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CAMBRIAN AND LOWER ORDOVICIAN TRILOBITES FROM NORTHWESTERN CANADA

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ABSTRACT

Fossils from six localities in the Cambrian and Lower Ordovician of the Mackenzie Valley and the Yukon-Alaska boundary, Canada, are listed; the trilobites are described, two genera and eight species being new. Correlations of the faunas are offered.

The trilobites described in this paper were collected at six localities in northwestern Canada, four in the Mackenzie Valley and two near the Yukon-Alaska boundary. They are of especial interest in that these areas lie between the Pacific and Arctic faunal provinces.

Several papers have been published by Cairnes, Hume, and Williams (1), to which the reader is referred for a description of the Cambro-Ordovician stratigraphy of the two regions.

Acknowledgments.—To Mr. L. D. Burling, Dr. G. S. Hume, and Dr. M. Y. Williams, who collected the specimens; to Dr. G. A. Cooper and Dr. C. E. Resser, of the U. S. National Museum, and to Dr. E. M. Kindle, of the Geological Survey of Canada, who gave me many privileges and assistance in the study of the material, I tender my most hearty thanks.

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LOCALITIES AND FAUNAS

Mackenzie Valley:

1. Lower Lower Cambrian chocolate-colored shale, south side of Clark Mountain. *Olenellus mackenziensis* Kobayashi, n. sp.
2. Upper Lower Cambrian gray, somewhat calcareous shale, Carcajou River, Lat. 65°N. *Chancia? clusia* (Walcott).
3. Upper Lower Cambrian reddish sandstone, Cap Mountain Ridge. *Redlichia?* sp., *Dolichometopsis humei* Kobayashi, n. sp., *Chancia canadensis* Kobayashi, n. sp.
4. Middle Cambrian chocolate-colored shale, Saline River at forks 8 miles above the mouth. *Glossopleura williamsi* Kobayashi, n. sp.

Yukon-Alaska boundary region:

5. Upper Cambrian white limestone in a section measured at Jones Ridge, north of Tatonduk River. The fossiliferous strata are alternating bands of rubbly and massive limestone. *Obolus* sp., *Acrotreta* sp., *Agnostus subobesus* Kobayashi, n. sp., *Parabolinella? punctolineata* Kobayashi, n. sp., *Ptychopleura brevifrons* Kobayashi, n. gen. and sp.
6. Lower Ordovician white limestone at a higher horizon in the section at locality 5. *Eoorthis* aff. *E. linecosta* Walcott, *Syntrophina* sp., *Symphysurina* aff. *S. woosteri* Ulrich.
7. Upper Cambrian(?) white limestone in a section on Squaw Mountain, north of Tatonduk River. *Obolus hamburgensis* (Walcott), *Obolus* (*Westonia*) *linguloides* Kobayashi, *Acrothele burlingi* Kobayashi, *Acrotreta* cf. *A. curvata* Walcott, *Yukonaspis kindlei* Kobayashi, n. gen. and sp., *Symphysurina spicata* Ulrich.
8. Lower Ordovician white limestone 330 feet higher in the section at locality 7. *Acrothele* sp., *Eoorthis* sp., *Syntrophina* sp., *Symphysurina* sp.

CORRELATIONS

Although each lot contains a small number of species, the data yielded are of value because the region is but little known and lies between the Pacific and Arctic provinces.

Mackenzie Valley.—The horizon of *Olenellus mackenziensis* is thought to be the lowest one represented and is probably lower Lower Cambrian. Its characterizing species is an intermediate form between *O. arcticus*, of the Wulff River formation of northwest Greenland, and *O. gilberti*, from the lower Lower Cambrian of Nevada.

The horizons with *Chancia? clusia* and *Dolichometopsis humei* appear to follow the *Olenellus* horizon, although it cannot be stated certainly which of the two is higher. Because of the common occurrence of *Chancia? clusia*, the horizon with this species is safely correlated with the upper Mount Whyte of British Columbia.

According to Poulsen, *Inglefieldia* (*Chancia*) occurs in the upper Lower Cambrian of Greenland, British Columbia, and Alberta; *Dolichometopsis* in the upper Lower Cambrian of Greenland. Furthermore, *Chancia canadensis* is very close to *Ptychoparia cuneas* Walcott. If we give weight to these points, the two fossil zones from the Mackenzie area are contemporaneous with the Cape Kent formation of Greenland and the upper Mount Whyte of British Columbia.

Although *Redlichia?* sp. is represented by a poor specimen, as seen in the illustration, it hints that the *Redlichia* beds widely spread between the western Pacific regions and Persia may correspond to some part of the Mount Whyte formation, probably higher than the lower Mount Whyte, because on one hand the genus is recognized to be a later stage of development of the mesonacid line, whereas on the other hand the *Redlicha* fauna appears to be older than the *Albertella* assemblage. To settle this point more perfect material is needed.

As *Glossopleura* is a prominent member of the Stephen fauna, of western North America and Greenland, the horizon with *Glossopleura williamsi* represents unquestionably the Middle Cambrian, probably some part of its lower half.

Accordingly the fossil horizons in the Mackenzie Valley may be correlated thus:

British Columbia	Mackenzie Valley	N.W. Greenland
Stephen	*Glossopleura* horizon	Cape Wood
Upper Mount Whyte	*Dolichometopsis* horizon	Cape Kent
	Chancia? clusia horizon	
Lower Mount Whyte	*Olenellus* horizon	Wulff River

Yukon-Alaska boundary.—In the collection at hand the *Albertella* fauna is not represented, but it has been found in the Tatonduk-Nation district of Alaska. Previous work and new observations on the geology of the district were summarized in 1932 by Mertie (4). The rock succession of the calcareous complex is said to rest

upon the pre-Cambrian (?) Tindir sedimentary group and to be divisible as follows:

1. Upper Cambrian limestone which grades upward without any noticeable stratigraphic or lithologic break into Ordovician limestone.
2. Upper plate of Middle Cambrian limestone.
3. A thin formation of slate and quartzite, also of Middle Cambrian age.
4. Lower plate of Middle Cambrian limestone.

The older part of the fauna appears to range in age from late Early to Medial Cambrian, but as unfortunately none of the material has been closely examined, precise discussion cannot be undertaken.

The late Late Cambrian part of the collection has, however, been investigated by the writer (5). These fossils were procured from a massive white to light-gray limestone that outcrops on Hard Luck Creek and that probably includes Upper Cambrian and Lower Ordovician horizons. The fauna includes the following species:

Eoorthis? sp., *Obolus hamburgensis* (Walcott), *Obolus tetonensis* Walcott, *Obolus* (*Westonia*) *linguloides* Kobayashi, *Dicellomus*? sp., *Acrothele burlingi* Kobayashi, *Acrotreta* aff. *sagittalis* (Salter), *Acrotreta* cf. *curvata* Walcott, *Pseudagnostus* (*Plethagnostus*) *clarki* Kobayashi, *Tatonaspis alaskensis* Kobayashi, *Chuangiella intermedia* Kobayashi, *Briscoia robusta* Kobayashi, *Briscoia septentrionalis* Kobayashi, *Briscoia mertiei* Kobayashi, *Parabriscoia elegans* Kobayashi, *Parabriscoia stenorachis* Kobayashi, *Parabriscoia*? *tripunctata* Kobayashi, *Hungaia*? *pacifica* Kobayashi, *Eurekia*? sp.

I consider this fauna to be approximately contemporaneous with the Fengshanian fauna of eastern Asia, that of the late Late Cambrian (including the early Ozarkian of Ulrich) of North America, and that of the upper *Lingula* flags of England.

The species from Jones Ridge and Squaw Mountain described in the present paper amplify the *Briscoia* fauna of the Alaska-Yukon boundary region. Although there is no common species of trilobite, the two assemblages of species belong probably to the *Briscoia* fauna in a broad sense, as the presence of the common species of brachiopods attests. The occurrence of *Symphysurina spicata* Ulrich at Squaw Mountain, however, indicates that the *Symphysurina* horizon might be at a somewhat higher level than that of the *Briscoia* horizon itself. The horizons containing *Symphysurina* aff. *S. woosteri* and *Symphysurina* sp. occupy higher stratigraphic positions than the *Briscoia* beds, which fact makes it possible for them to be the base of the Ordovician and contemporaneous with the Cape Clay formation of Greenland and its equivalent in North America.

BRIEF NOTES ON CAMBRIAN AND EARLY ORDOVICIAN FAUNAS

The *Olenellus* fauna of the early Early Cambrian is recognized throughout the whole length of the Cordillera from California to the Mackenzie district, and in Greenland. The *Redlichia* fauna is similarly widespread on the western side of the Pacific. The actual relationship between the stratigraphic successions on the two sides of the Pacific basin is still in question, but there is some reason to believe that the *Redlichia* beds may be higher than the *Olenellus* beds. In

north Chosen *Protolenus coreanicus* was recently discovered by K. Saito (6) at a horizon lower than those of the *Redlichia* beds; in Yunnan the *Redlichia* fauna contains *Palaeolenus*, a genus which belongs unquestionably in the general group of *Protolenus*. Not only these faunal considerations but also the fact that *Redlichia* itself is considered by many paleontologists to be a descendant of the mesonacid trilobites adds weight to this conclusion.

The *Dolichometopsis* faunule in the Mackenzie district unites the upper Mount Whyte formation in British Columbia and the Cape Kent in Greenland.

The Ptarmigan fauna has not yet been discovered in the Mackenzie district, but is recorded from the International Boundary region. It appears to have a wide distribution on the eastern side of the north Pacific, but is so far unknown outside of this region. The so-called *Albertella* from Manchuria is represented only by the pygidium, which is, as noted elsewhere (7), quite different from that of *Albertella*, s.s., from the Ptarmigan; it was collected from a horizon high up in the Kushan beds of the late Middle Cambrian. Thus the occurrence of *Albertella* in eastern Asia is quite uncertain.

The Stephen formation in western Canada contains several remarkable faunas. The *Glossopleura* fauna and the *Tonkinella-Oryctocephalus* fauna are of particular interest. The former occurs in western North America and Greenland, while the latter (8) occurs

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EXPLANATION OF PLATE 21

All types are in the National Museum of Canada, Ottawa.
Photographs by H. Kobayashi

FIGS. *1–2—Agnostus subobesus* Kobayashi, n. sp., syntypes, cephalon and pygidium, ×4, Upper Cambrian; N.M.C. 8717, *a*. (p. 161)

3–6—Yukonaspis kindlei Kobayashi, n. gen. and sp., cranidia, ×3; Upper Cambrian. *3, 4*, Holotype; *5, 6*, paratypes; N.M.C. 8717, *a, b*. (p. 164)

7, 8—Ptychopleura brevifrons Kobayashi, n. gen. and sp., cranidia, ×4; Upper Cambrian. *7*, Holotype; *8*, paratype; N.M.C. 8719, *a*. (p. 165)

9–14—Symphysurina aff. *S. woosteri* Ulrich, hypotypes, Lower Ordovician. *9, 10*, Two views of a pygidium; *12, 13*, two views of a free cheek; *14*, cranidium; ×2. *11*, Another pygidium, ×1½. N.M.C. 8722, *a–c*. (p. 164)

15—Symphysurina spicata Ulrich, hypotype, pygidium, ×3; Upper Cambrian (?); N.M.C. 8720. (p. 164)

16–18, 21–23—Glossopleura williamsi Kobayashi, n. sp., syntypes, Middle Cambrian. *16*, Cranidium; *18*, a free cheek; ×2. *17*, Part of thorax and pygidium; *21, 22*, pygidia; *23*, external mold of a complete carapace; ×1½. N.M.C. 8711, *a–e*. (p. 163)

19, 20—Parabolinella? punctolineata Kobayashi, n. sp., ×2; Upper Cambrian. *19*, Holotype, cephalon; *20*, paratype, free cheek; N.M.C. 8721, *a*. (p. 166)

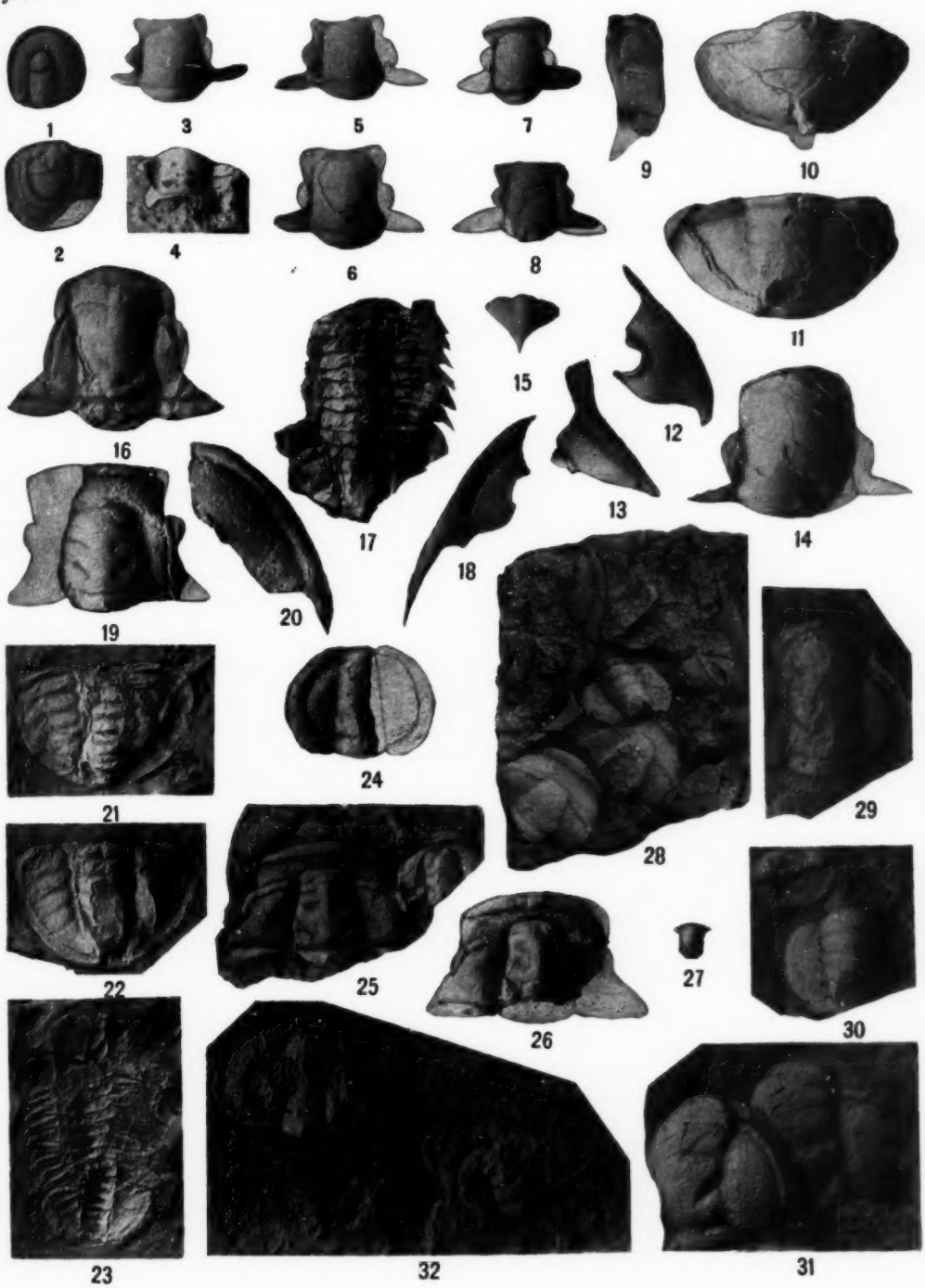
24—Redlichia? sp., part of cranidium, ×2; Lower Cambrian; N.M.C. 8715. (p. 162)

25–27—Chancia? clusia (Walcott), hypotypes, Lower Cambrian. *25*, cranidium; *27*, an associated hypostoma; ×3. *16*, Another cranidium, ×2. N.M.C. 8713, *a*. (p. 165)

28—Chancia canadensis Kobayashi, n. sp., syntypes, cranidia, ×2; Lower Cambrian; N.M.C. 8714. On the same slab are a pygidium and free cheeks of *Dolichometopsis humei*. (p. 164)

29–31—Dolichometopsis humei Kobayashi, n. sp., syntypes, ×2; Lower Cambrian. *29, 31*, Cranidia; *30*, pygidium; N.M.C. 8712, *a*. (p. 162)

32—Olenellus mackenziensis Kobayashi, n. sp., ×4; Lower Cambrian; N.M.C. 8716. Cephalon at left, holotype; at right, paratype. (p. 161)



Kobayashi, Cambrian and Ordovician Trilobites

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in the Pacific basin from western North America to eastern and southern Asia and even Australia. The latter fauna contains *Olenoides* quite commonly, a genus which in turn is known to occur in Siberia (9). The mutual relations of the two faunal zones is still uncertain in western North America, but, according to C. E. Resser, the latter may be higher than the former in the Mount Bosworth section. If such is the case, a fairly good agreement with the succession in Chosen and Manchuria is recognizable, because the *Glossopleura* beds probably correspond to the *Amphoton* beds, which there are unquestionably lower than the *Tonkinella-Oryctocephalus-Olenoides* beds.

The Kushan fauna is unrepresented, or replaced in the Cordillera of North America by some fauna quite distinct from it.

The still higher *Briscoia* fauna, s. l., occurs on both sides of the Pacific through Alaska and marks the late Late Cambrian.

As shown in another paper (10), *Symphysurina* has a northern distribution and *Kainella* a southern, but the two are approximately contemporaneous and indicate the base of the Ordovician. The present study raises question as to the geological range of the genus *Symphysurina*, and future research must be relied on for information as to whether or not it appears in the latest Late Cambrian. *Symphysurina spicata* Ulrich is associated with brachiopods of the *Briscoia* fauna, but in the collection from the Squaw Mountain section, which includes *S. spicata*, the species is not accompanied by any trilobites likewise characteristic of the *Briscoia* fauna, s. s. The fauna may therefore be taken to represent the earliest Ordovician, with the further assumption that the atremate and neotremate brachiopods range through late Late Cambrian and early Early Ordovician time. It is also noted that *Dictyella? mansuyi*, from the latest Late Cambrian of Indo-China, is in its pygidium hardly distinguishable from *Symphysurina*.

SYSTEMATIC DESCRIPTIONS

Genus AGNOSTUS Brongniart

AGNOSTUS SUBOBESUS Kobayashi, n. sp.

Plate 21, figures 1, 2

This species belongs unquestionably to the general group of agnostids typified by *A. pisiformis* var. *obesus* (11). It is characterized by the absence of a longitudinal preglabellar furrow, its broad marginal border, minute posterior spine, and obscure second furrow on the axis of the pygidium. By the latter feature it is distinct from *A. obesus* of northern Europe, *A. insuetus* (12) of northeastern America, and *A. chiushuensis* (13) of South Manchuria.

Formation and locality.—Upper Cambrian white limestone in section measured at Jones Ridge, north of Tatonduk River, International Boundary.

Syntypes.—Nat. Mus. Canada 8717, *a*.

Genus OLENELLUS Hall

OLENELLUS MACKENZIENSIS Kobayashi, n. sp.

Plate 21, figure 32

Cephalon semicircular in its anterior two-thirds; from its postero-lateral ends a pair of genal spines extend in a direction continuous with the lateral margin;

posterior third of the cephalon narrows regularly backward from the spines; intergenal angle about 130°; occipital margin straight; marginal brim narrow and rounded; glabella convex, elevated above the cheeks, relatively short, leaving a narrow preglabellar area; frontal lobe of the glabella circular; the rest of it subcylindrical, gently contracted in the middle and divided into four unequal lobes by transverse furrows which are not continuous across the axis; palpebral lobe large, as wide as the glabella; its band elevated to the same level as the glabella.

Observations.—The species is represented by a nearly complete and two incomplete cephala. None of these specimens show a longitudinal ridge across the preglabellar area. The intergenal angle is much wider in the paratype and measures 150°.

Comparisons.—In the general outline of the cephalon and glabella this species resembles *O. canadensis* (14), but differs from it in its shorter glabella and larger palpebral lobe. *O. gilberti* (15) and *O. arcticus* (16) have preglabellar fields, but neither has significant intergenal angles. The outline of the glabella and palpebral lobes of *O. arcticus* is similar to that of *O. mackenziensis;* in *O. arcticus* also the brim and palpebral band are much thicker and the frontal lobe of the glabella is extraordinarily large. *O. mackenziensis* is thus somewhat intermediate in character between *O. arcticus* and *O. gilberti.*

Formation and locality.—Chocolate shale on the south side of Clark Mountain, Mackenzie district; it is accompanied by an atremate brachiopod and *Stenotheca*? sp.

Types.—Holotype and paratype, Nat. Mus. Canada 8716.

Genus REDLICHIA Cossmann

REDLICHIA? sp.

Plate 21, figure 24

An incomplete cranidium with long conical glabella, an occipital and three lateral furrows, all running transversely across the glabella, and a large semicircular eye-band attached to the glabella.

The specimen reveals some resemblances to the Mesonacidae and Zacanthoididae. In outline alone it agrees fairly well with some genera of the Mesonacidae, such as *Callavia* and *Nevadia*, but the presence of the ordinal facial suture separates it from the family. *Zacanthoides* and *Albertella* have huge eye-bands, such as are seen in this species, but they do not agree with it in the outline of the glabella, which in them is subparallel or expanded forward. They also differ in the glabellar furrows, which do not run transversely across the glabella as in this species.

The only other genus near enough to consider is *Redlichia*, with which all the characters observable on the specimen fit exactly. Unfortunately however, the specimen is fragmentary, and as *Redlichia* so far is known only in the western Pacific region, I hesitate somewhat to make such a reference.

Formation and locality.—Late Lower Cambrian of Cap Mountain Ridge, Mackenzie District, Canada.

Holotype.—Nat. Mus. Canada 8715.

Genus DOLICHOMETOPSIS Poulsen

DOLICHOMETOPSIS HUMEI Kobayashi, n. sp.

Plate 21, figures 29–31

In the cranidium this species resembles *Glossopleura williamsi* very closely, but differs from it in its wider palpebral lobe, and in its fixed cheek, which widens forward from the eye and has a narrow, depressed frontal border. The presence of the border not only distinguishes this species from *G. williamsi*, but also from the entire genus *Glossopleura.*

Specimens preserved in sandstone show four pairs of glabellar furrows very distinctly. The free cheek accompanying the cranidium has spines starting a little forward from the basal margin, but not as far anterior as in the genotype. The pygidium is smaller than the cephalon,

subovate, and bounded by a convex border; axial lobe conical, elevated and consisting of about five segments; pleural lobes depressed; pleural ridges swing back gently.

The general aspect of the cranidium and pygidium is very suggestive of *Albertella*, the absence of the spines on the pygidium, however, being an important difference.

Formation and locality.—Late Lower Cambrian reddish sandstone of Cap Mountain Ridge, Mackenzie district.

Syntypes.—Nat. Mus. Canada 8712, *a*.

Genus GLOSSOPLEURA Poulsen

GLOSSOPLEURA WILLIAMSI Kobayashi, n. sp.

Plate 21, figures 16–18, 21–23

This species is most closely related to *Glossopleura walcotti* Poulsen (17), from the Cape Wood formation of Cape Kent, northwest Greenland, but it may be distinguished by its broader glabella, shorter palpebral lobe, narrower lateral border, and longer genal spine on the free cheek; the shape of the pleural extremities of the thoracic segments, straight articulating margin, and narrower marginal border on the pygidium. The facial sutures anterior to the eyes curve in gently in *williamsi*, whereas they diverge quickly in *walcotti*.

Formation and locality.—Middle Cambrian chocolate shale; Saline River at fork 8 miles above the mouth, Mackenzie district.

Syntypes.—Nat. Mus. Canada 8711, *a–e*.

Genus SYMPHYSURINA Ulrich

Symphysurina ULRICH, *1924*, in Walcott, Smithsonian Misc. Coll., vol. 74, no. 1, p. 37.—ULRICH, *1925*, in Walcott, Smithsonian Misc. Coll., vol. 75, no. 3, p. 108.—POULSEN, *1927*, Jubilaeumsekspeditionen Nord ôm Grønland, no. 3, p. 286.

Genotype: *Symphysurina woosteri* Ulrich.

Smooth pygidia with a posterior spine are frequently found in Upper Cambrian and Lower Ordovician rocks. *Dictyella* (18), from the upper Upper Cambrian of eastern Asia, has such a pygidium with the spine produced backward from the marginal border; *Symphysurina*, from lower Lower Ordovician beds extending from Greenland to North America, has no marginal border but does have a spine extending backward from the axis itself. *Dictyella*? *mansuyi* (19), from the upper Upper Cambrian, however, has a pygidium with caudal spine of *Symphysurina* type, but a cranidium more like that of the tsinanids. The true generic position of this species is at present in question.

Posterior spines are found in the Lower Ordovician Asaphidae, such as *Megalaspis*, *Xenostegium*, and *Thysanopyge* (20); the pygidia usually have marginal borders. *Xenostegium*, s. s., is distinguished from *Megalaspis* by obsolescence of the axial furrows in the posterior portion. *Thysanopyge* is well marked by the indented margin of the posterior spine. Generally speaking, the pygidia of *Dictyella* and *Symphysurina* are very smooth those of *Megalaspis*, *Xenostegium*, and *Thysanopyge* are somewhat segmented; whereas those of a new Middle Cambrian genus in the present author's hands (7), *Bathyurus* and *Goniurus* of the Lower and Middle Ordovician, and *Dalmanites* of the Silurian and Devonian have clear-cut segmentation. Though these distinctions serve to separate the pygidia with caudal spines one from another, nevertheless the generic identification is sometimes difficult to make from this part alone.

Geological and geographical distribution.—British Columbia, Alberta, Nevada, upper Mississippi valley, Quebec region, and Greenland. This genus has hitherto been considered an indicator of the lower Lower Ordovician in North America, but the discovery of *S. spicata* in the Upper Cambrian(?) of the Yukon district seems to point toward an earlier appearance, in the upper Upper Cambrian.

SYMPHYSURINA aff. S. WOOSTERI Ulrich

Plate 21, figures 9–14

Symphysurina woosteri ULRICH, *1924*, in Walcott, Cambrian and Lower Ozarkian trilobites: Smithsonian Misc. Coll., vol. 75, p. 37, pl. 37, fig. 8.—ULRICH, *1925*, in Walcott, Cambrian and Ozarkian trilobites: Smithsonian Misc. Coll., vol. 75, p. 115, pl. 21, figs. 1–11.

Cranidium, free cheek, and pygidium are in hand. As the cranidium is slightly crushed obliquely, the longitudinal ridge and median tubercle cannot be seen. Glabella a little longer than that of the type specimen, but in most characters in close agreement with it. Free cheek exactly the same as in type. The pygidium in Walcott's fig. 9 has a much stouter axis than those in his figs. 10–11. The present pygidium is closer to the latter form, but the axial lobe is not so well defined as in either one. Except for these minor differences this trilobite is very close to *S. woosteri*.

Formation and locality.—Lower Ordovician white limestone in section measured at Jones Ridge, north of Tatonduk River, International Boundary.

Hypotypes.—Nat. Mus. Canada 8722, *a–c*.

SYMPHYSURINA SPICATA Ulrich

Plate 21, figure 15

Amphyx? sp., WALCOTT, *1884*, U. S. Geol. Survey, Mon. 8, pl. 12, fig. 19.

Symphysurina spicata ULRICH, *1925*, in Walcott, Cambrian and Ozarkian trilobites: Smithsonian Misc. Coll., vol. 75, no. 3, p. 113, pl. 21, figs. 12–18.

Only a single small pygidium is in hand; broadly triangular; axial furrows in anterior half, dying out gradually backwards; no marginal border; small posterior spine projecting from end of axis. The specimen, as far as details can be seen, agrees exactly with the pygidium illustrated in Walcott's Plate 21, fig. 18.

Formation and locality.—Upper Cambrian(?) white limestone in the section on Squaw Mountain, north of Tatonduk River, International Boundary.

Holotype.—Nat. Mus. Canada 8720.

Genus YUKONASPIS Kobayashi, n. gen.

This form appears similar to *Illaenurus*, *Cholopilus*, and *Chuangiella*, but it has no trace of a frontal brim. *Tatonaspis* (5) has this kind of anterior margin, but differs from *Yukonaspis* in its evenly convex cranidium; square, obscurely defined glabella; and other features of the frontal limb.

Genotype: *Yukonaspis kindlei* Kobayashi.

Geological and geographical distribution.—Upper Cambrian of northwestern North America.

YUKONASPIS KINDLEI Kobayashi, n. sp.

Plate 21, figures 3–6

Glabella elongate, oblong, convex, with no furrows on it except for the occipital one; circumglabellar furrow distinct; fixed cheek very narrow across the eyes, its postero-lateral limb however extended laterally to some distance; eyes of medium size, elevated and located at the midlength of the cranidium; practically no frontal limb and rim; anterior margin considerably bent at the middle; facial sutures anterior to the eyes parallel to each other and then incurved; surface smooth.

Formation and locality.—Upper Cambrian(?) white limestone in the section on Squaw Mountain, north of Tatonduk River, International Boundary.

Types.—Holotype and paratypes, Nat. Mus. Canada 8718, *a*, *b*.

Genus CHANCIA Walcott

CHANCIA CANADENSIS Kobayashi, n. sp.

Plate 21, figure 28

Specific characters are the relatively wide cranidium, short glabella, and obsolete furrows. This species differs from *Ptychoparia cuneas* Walcott (21) by its smaller and less significant frontal brim, and narrower postero-lateral limb of the fixed cheek; and from *Solenopleura borealis* Poulsen (22) by the posterior

position of the eyes. The middle of the frontal limb is somewhat elevated and very faintly defined by shallow grooves which diverge forward.

Formation and locality.—Late Lower Cambrian red sandstone; Cap Mountain Ridge, Mackenzie district.

Syntypes.—Nat. Mus. Canada 8714.

CHANCIA? CLUSIA (Walcott)

Plate 21, figures 25–27

Ptychoparia clusia WALCOTT, *1917*, Fauna of the Mount Whyte formation. Smithsonian Misc. Coll., vol. 67, no. 3. p. 85, pl. 2, figs. 3,3*a*.

Neglecting minor differences as due to individual variation, the specimens in hand certainly reveal very close agreement with the type in subtrapezoidal cranidium, long glabella, prominent median ridge, deep dorsal and glabellar furrows, median tubercle on the neck, median and short palpebral lobe, prominent ocular ridge, narrow frontal limb, elevated frontal brim, and rough-textured surface.

In the Canadian specimens four pairs of glabellar furrows are all distinct, but in the holotype the first pair is obscure. The size of the frontal limb and convexity of the brim differ among the specimens. In one a pair of obscure furrows diverge forward from the anterolateral angles of the glabella and bound an obscure trapezoidal area, in which the triangular posterior projection of the brim is faintly seen.

Since little has been published concerning the facial suture and hypostoma of this species, these observations on the new material are added here. The sutures are almost parallel to each other anterior to the eyes, but gradually become incurved and intramarginal in crossing the brim; posterior branches of the suture rather regularly diagonal. The hypostoma has a pair of triangular anterior wings; central body convex, subovate, its lateral and posterior sides surrounded by a groove and brim.

Formation and locality.—Late Lower Cambrian shale, Carcajou River, Lat. 65°, northern Mackenzie River, Canada.

Hypotypes.—Nat. Mus. Canada 8713, *a*.

Genus PTYCHOPLEURA Kobayashi, n. gen.

There are several genera intermediate between the Ptychoparidae and Solenopleuridae. An unnamed genus in the author's hands (7) has a semiovate glabella but also other characters much allied to those of the Ptychoparidae. *Solenopleurella* (23) exhibits its solenopleurid alliance except for its square glabella. *Ptychopleura* shows close affinity to *Solenopleurella*, but differs in the presence of a narrow and distinct frontal limb, narrow fixed cheek, weak glabellar furrows, and in the absence of an ocular ridge. A second unnamed genus (7) is also close to this genus, but lacks a frontal limb. Further observations are included in the description of the genotype.

Among the Levis faunas, *Menocephalus sedgwicki* (Billings) (24) probably belongs to *Ptychopleura*.

Genotype: *Ptychopleura brevifrons* Kobayashi.

Geological and geographical distribution: Upper Cambrian of Canada.

PTYCHOPLEURA BREVIFRONS Kobayashi, n. sp.

Plate 21, figures 7, 8

Glabella convex, subquadrate, narrowing forward slightly; three pairs of weak glabellar furrows, but occipital and dorsal furrows strong; frontal limb narrow, as wide as the fixed cheek across the eyes; frontal brim convex, elevated in the middle; palpebral lobe located at the midlength, not accompanied by an ocular ridge; lateral limb of the fixed cheek triangular, of moderate size; facial sutures divergent both anterior and posterior to the eyes; surface finely granulated.

Comparisons.—*P. brevifrons* differs from *Arionellus cylindricus* Billings mainly in the strength of the glabellar furrow. The glabella is also more rounded in front and the eyes may be somewhat larger and more anterior in position.

Formation and locality.—Upper Cambrian white limestone in section measured at Jones Ridge, north of Tatonduk River, International Boundary.

Types.—Holotype, paratype, Nat. Mus. Canada 8719, *a*.

Genus PARABOLINELLA Brögger

PARABOLINELLA? PUNCTOLINEATA Kobayashi, n. sp.

Plate 21, figures 19, 20

Glabella truncato-conical, moderately convex, surrounded by a deep dorsal furrow and provided with two pairs of oblique glabellar furrows; palpebral lobe slightly anterior to the middle, medium size, half as wide as the glabella; preglabellar field large, moderately convex, gently inclined forward and covered by nerve-like lines which terminate in a row of pits along the raised transverse frontal brim; facial sutures slightly divergent anterior to the eyes and diagonal posterior to them.

Comparisons.—This species is very close to *Parabolinella evansi* which may be distinguished by the more posterior eye provided with a distinct ocular ridge and the absence of a row of pits in the latter. *Moxomia angulata* (15) has a row of pits and the eyes well forward, but it differs from *P.? punctolineata* in the transverse nerve-like lines, wide parallel-sided glabella, and in the median tubercle on the occipital ring. The divergence of the anterior facial suture is seen in the Olenidae only in *Parabolinella*, from which, so far as the cranidium is concerned, this species does not reveal any difference of generic value. *P. laticauda* (26) strikingly resembles *P.? punctolineata*, only minor differences being found—three, instead of two, pairs, of glabellar furrows; absence of the row of pits along the frontal brim; occipital margin straight, not bending forward as commonly seen in *Parabolinella* and other genera of the Olenidae. The taxonomic position of the Pacific species in the olenid alliance, however, remains tentative. Until more evidence has been accumulated the generic references must remain provisional.

Formation and locality.—Upper Cambrian white limestone in section measured at Jones Ridge, North of Tatonduk River, International Boundary.

Types.—Holotype, paratype, Nat. Mus. Canada 8721, *a*.

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STRATIGRAPHIC SIGNIFICANCE OF MIOCENE, PLIOCENE, AND PLEISTOCENE PECTINIDAE IN THE SOUTHEASTERN UNITED STATES

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ABSTRACT

A brief résumé of the stratigraphy of deposits ranging in age from medial Miocene to Pleistocene in the southeastern United States is followed by a statement of the distribution and characteristics of the Pectinidae in these deposits. Tables show the correlation of some of the deposits of the Atlantic and Gulf Coastal Plains, the geologic ranges of the Pectinidae, and the genetic relationships of the Pectinidae. Three new species and six subspecies are described.

The purpose of this paper is to show the value of the Pectinidae in the identification of units in the stratigraphic sequence of fossiliferous deposits of the Atlantic Coastal Plain that range in age from late medial Miocene (Chesapeake group) to Pleistocene. The Pectinidae of the Alum Bluff group (early and medial Miocene) of Florida and of other deposits of the same age in the southern Coastal Plain are considered only for comparison with allied forms in the other Miocene deposits.

The brief résumé of the stratigraphy of the Miocene, Pliocene, and Pleistocene deposits given below will serve as a background for the paleontologic discussion. It is incomplete, especially with respect to the Pliocene and Pleistocene.

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RÉSUMÉ OF STRATIGRAPHY

MARYLAND

Miocene (Chesapeake group).—The Miocene deposits of Maryland were admirably described in 1904 by W. B. Clark, G. B. Shattuck, and others (1*A*), and the discussion that follows is based largely upon that report.

The deposits of the Chesapeake group lie wholly within the tide-water region; on the Western Shore between the Chesapeake Bay and the Potomac River, extending inland as far as the District of Columbia; on the Eastern Shore in a broad belt between the Chester River on the north and Fishing Bay on the south. On both sides of the Chesapeake Bay the strike of the beds is northeast.

In Maryland the Chesapeake group has been separated into three formations, all of middle Miocene age—in ascending order, the Calvert formation (thickness about 200 feet), the Choptank formation (about 80 feet), and the St. Marys formation (about 74 feet). The Yorktown, the upper-

most formation of the Chesapeake group in Virginia, has not been recognized in Maryland.

The Calvert formation is divided by Shattuck (31*a*) into the Fairhaven diatomaceous earth, which is subdivided into three zones (zones 1–3); and the Plum Point marls, which are subdivided into twelve zones (zones 4–15). The Fairhaven diatomaceous earth member is especially characterized by diatomite. The Plum Point marl member consists of a series of sandy clays and clayey sands ranging in color from bluish-green to buff and containing a large assemblage of vertebrate and invertebrate remains.

The Choptank formation consists of reddish, yellowish, or greenish sand and sandy clay. Locally the materials are consolidated into hard rock. The formation is divided by Shattuck (31*b*) into five zones (zones 16–20). Zones 17 and 19 contain well preserved fossils in great abundance.

The St. Marys formation consists of clay, sand and clayey sand. The clay is usually of a dark color. The formation is divided by Shattuck into four zones (zones 21–24) (31*c*). The basal zone (zone 21), consists mainly of drab clay and appears to be devoid of fossils. The three other zones are fossiliferous, some parts being almost entirely composed of shells.

Pleistocene (*fossiliferous deposits only*).—The Pamlico formation, containing well preserved fossils, is excellently exposed in Wailes Bluff, on the north shore of the Potomac River 3 miles northwest of Point Lookout; and at Langleys Bluff, on the shore of Chesapeake Bay about 5½ miles south of Cedar Point. The fossils from these localities and the literature pertaining to them are discussed by Mansfield (18*a*).

NEW JERSEY

Miocene (*Kirkwood formation*).—An important work on the Miocene of New Jersey was published in 1894 by Whitfield (42). Many of the species recorded in this monograph are reported to have come from marl pits in the Kirkwood formation (middle Miocene) at Shiloh, Cumberland County. Pilsbry and Harbison (28) have recently described new species of mollusks collected from unused marl dug some years ago from Shepherd's pit, near Shiloh.

In 1929 I obtained two collections of fossils from marl thrown out of pits, one 2½ miles nearly west, and the other 3 miles northwest of Shiloh. A number of species in these collections are the same as species in the Calvert formation in Maryland and are believed to have lived in Calvert time. Miocene deposits younger than the Kirkwood formation may occur south of the Shiloh area.

VIRGINIA

Miocene (*Chesapeake group*).—The Chesapeake group of Virginia is divided into four formations. In ascending order the estimate thicknesses are: Calvert, 200 feet; Choptank, 50 feet or more; St. Marys, 180 feet; Yorktown, 145 feet; total for the group, 575 feet.

The divisions of the Chesapeake group, as recognized by me(19*a*), are:

Upper Miocene.

Yorktown formation.

Zone 2, or *Turritella alticosta* zone.
Upper part.
Middle part.
Lower part, including *Chama*-bearing bed.
Zone 1, or *Pecten clintonius* zone.
Middle Miocene.
St. Marys formation.
Zone 2, or *Crassatellites meridionalis* zone.
Zone 1, or *Bulliopsis quadrata* zone.
Stratum A.
Choptank formation.
Calvert formation.

The Calvert formation consists of dark-gray or olive sandy, usually diatomaceous clay.

The Choptank formation, where recognized, consists of dark-brown rather soft sand and greenish-gray clayey sand alternating with indurated sandstone layers.

In the St. Marys formation the lower part, or stratum *A*, consists of a nearly unfossiliferous dark sandy plastic clay. The overlying fossiliferous part is divided into two faunal zones.

The Yorktown formation is separated into two faunal zones.

Zone 1, or *Pecten clintonious* zone, includes, in part, the Murfreesboro stage of Olson (26). (The term "Murfreesboro" is preoccupied, having been used by Safford and Killebrew (34) to designate the lowest limestone of the Central Basin of Tennessee.) As the fauna of this zone is more closely related to the fauna of the Yorktown formation than to that of the St. Marys formation, I have placed it in the Yorktown.

Zone 2, or *Turritella alticosta* zone, is divisible into three minor parts. The lowest consists of coarse sand containing many specimens of *Chama* and other fossils; it is excellently exposed in a bluff on the north shore of the James River east of the Old Kings Mill Wharf. In a section of the bluff given by Stephenson, Cooke, and Mansfield (35*a*), the *Chama*-bearing bed is indicated by "bed *w*" and is underlain by zone 1 of the formation. Higher beds in the lower part of zone 2, exposed in the same bluff above the *Chama*-bearing bed, are indicated (35*a*) by "beds *x*, *y*, *z*," and consist of gray to buff sands and laminated clay. Equivalent beds at Yorktown are indicated (35*b*) by "beds *a*, *b*, *c*, *d*." The fragmental beds of zone 2 (middle part) consist of sands and cross-bedded clays containing broken and entire shells and are typically exposed in the bluffs at Yorktown. This middle part is indicated (35*b*) by "beds *e*, *f*." The upper part of zone 2 overlies the fragmental beds and is typically exposed at Suffolk. These beds consist largely of gray to blue sands that oxidize to buff.

NORTH CAROLINA

Miocene.—The Yorktown formation (late Miocene) in the northern part of the State contains a fauna suggestive of deposition in colder water than that of the beds in the southern part of the State (20*a*). The cold-water fauna apparently lived in an embayment whose waters transgressed the older rocks of the Piedmont plateau; the fauna, especially that near the inner shore line, was consequently somewhat protected from the influence of the warmer

oceanic waters that lay east of the embayment.

Beds like those of the Yorktown formation of Virginia were deposited in the northern part of the Coastal Plain of North Carolina, but in places their exact position within the Yorktown is not easily determinable. The St. Marys formation probably underlies the Yorktown and is revealed only at very low water stages of the streams.

At Murfreesboro, on the Meherrin River, zone 1 of the Yorktown formation forms the lower bed, and is overlain by a bed corresponding to the bed carrying many *Chama* at Old Kings Mill Wharf on the James River, Virginia. The same fauna occurs around Halifax and at several other localities. The faunas at other localities in North Carolina resemble, and appear to be nearly equivalent to, those of the middle and upper parts of zone 2 of the Yorktown formation.

The latest late Miocene fauna in the northern part of the State is exposed at Tar Ferry, on Wiccacon Creek. It appears to be comparable in age with that of the Duplin marl at Natural Well, and is a little younger than that of the uppermost Yorktown exposed in the vicinity of Suffolk, Virginia.

In the southern part of the Coastal Plain the Duplin marl, uppermost Miocene, occurs in patches, as at Natural Well, and elsewhere. The formation contains a fauna suggestive of deposition in warmer water than that of corresponding deposits farther north in North Carolina and Virginia.

Pliocene.—In the northeastern part of the State the Croatan sand is exposed in the right bank of the Neuse River, 9 to 15 miles below Newbern, and contains well-preserved fossils (18*b*).

In the southern part of the State abundantly fossiliferous strata of the Waccamaw formation overlie Cretaceous beds at Neills Eddy Landing and at Walkers Bluff on the Cape Fear River (24*a*).

SOUTH CAROLINA

Miocene.—The fauna at Raysors Bridge, on the Edisto River, lived in colder water than did the fauna of the Duplin marl. The character of the fauna indicates that it occupies a lower stratigraphic position in the upper Miocene than the Duplin, and it is correlated with zone 1 of the Yorktown formation.

The Duplin marl is exposed in the vicinity of Darlington, Darlington County; on the Muldrow place, 5 miles southwest of Mayesville, Sumter County; and at other places. The fauna at the Muldrow place is considered by Gardner and Aldrich (11*a*) to be of nearly the same age as that of the Duplin beds farther north.

Pliocene.—The fauna at the Grove Plantation on Cooper River, and at the Smith place (Yeaman's Hall) on Goose Creek, referred by Sloan to his "Goose Creek phase," is tentatively referred to the Pliocene, as it carries a few species not found with certainty in the Duplin marl. The fauna is considered a little older than that of the Waccamaw marl at Tilly's Lake, Waccamaw River, near Nixonville.

GEORGIA

Miocene.—The highest fossiliferous bed in the vicinity of Porters Landing, Savanna River, is of late Miocene age. This bed is assigned to the Duplin marl.

FLORIDA

Miocene.—The Alum Bluff group of Florida includes three formations: In ascending order, Chipola formation, Oak Grove sand, and Shoal River formation. Gardner has recently described the pelecypods in each of these formations (12).

Most of the gastropods and scaphopods and all the known pelecypods occurring in the Choctawhatchee formation has been described by me (21; 23; 23*A*), and I have indicated and illustrated the relative sequence of the deposits (23*a*). The *Yoldia* and *Arca* zones are referred to the upper middle Miocene. The *Ecphora* zone, aluminous clay, and *Cancellaria* zone are referred to the upper Miocene.

Pliocene and older(?).—According to Cooke and Mossom (8*a*)

> The deposits of Pliocene age in Florida are divisible into four formations, the Caloosahatchee marl, the Citronelle formation, the Bone Valley gravel, and the Alachua formation. These four may have been laid down at approximately the same time, although there is little direct evidence that they are of the same age. They accumulated in different ways. A fifth formation, the Charlton, is tentatively referred to the Pliocene.

Deposition of either marine or nonmarine beds was in progress during parts of early, medial, and late Pliocene time, and possibly throughout the Pliocene epoch, but insufficient work has been done to permit definite assignment of certain of the beds to their exact stratigraphic position within the Pliocene.

The Caloosahatchee marl along the Caloosahatchee River was laid down during some part of early Pliocene time. It has not been determined whether beds in certain areas, as in the vicinity of Buckingham, Acline, and elsewhere, were laid down during latest Miocene or earliest Pliocene time.

Papers recently published by Tucker and Wilson (38; 39) describe a number of new and interesting species from the Tertiary of southern Florida. Most of the new species and other species identified as occurring only in the Miocene elsewhere were collected at Acline, Charlotte County, a locality near Alligator Creek. The determination of certain species occuring at Acline which occur elsewhere only in the Miocene and not in the Caloosahatchee marl at its type locality suggests that the fauna at Acline is either latest Miocene, or earliest Pliocene, or a mixture of faunas of the two ages.

The fauna described by me (22) from limestone along Tamiami Trail in southern Florida was assigned to the upper part of the Caloosahatchee marl. There is a possibility that it should be assigned to the lower part of the Caloosahatchee marl instead of to the upper part, but there is no evidence to justify referring it to the Miocene.

Pleistocene.—The Pleistocene deposits of Florida are discussed by Cooke and Mossom (8*b*) and by Simpson (32*a*).

SUMMARY

The stratigraphic details treated above are summarized in Table 1, and the correlations are indicated by the usual conventions.

TABLE 1. CORRELATION OF SOME OF THE MIOCENE, PLIOCENE, AND PLEISTOCENE DEPOSITS OF THE ATLANTIC AND GULF COASTAL PLAIN

		EUROPEAN EQUIVALENT	NEW JERSEY	MARYLAND	VIRGINIA	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA
PLEISTOCENE				DEPOSITS AT WAILES BLUFF (a)			DEPOSITS ON YONGES ISLAND (a)		MARL ON NORTH CREEK (a)
PLIOCENE	UPPER	SICILIAN (ASTIAN)				?	?		DEPOSITS ON MYAKKA RIVER (d)
	MIDDLE	ASTIAN				?	?		?
	LOWER	PLAISANCIAN				CROATAN SAND IN NORTH; WACCAMAW FORMATION IN SOUTH	WACCAMAW FM. (c)		LIMESTONES OF TAMIAMI TRAIL (e); CALOOSAHATCHEE MARL
MIOCENE	UPPER	BAHELIAN: PONTIAN			YORKTOWN FORMATION, ZONE 2: BEDS AT SUFFOLK	UPPERMOST YORKTOWN; DUPLIN MARL	DUPLIN MARL	DUPLIN MARL (FORTENS LD.)	CHOCTAWHATCHEE FORMATION: CANCELLARIA ZONE: UPPER PART
					BEDS AT YORKTOWN	EQUIVALENT OF BEDS AT YORKTOWN, VA.			CANCELLARIA ZONE: LOWER PART
					CHAMA-BEARING BED	EQUIVALENT OF CHAMA-BEARING BED			ALUMINOUS CLAY
		SARMATIAN			ZONE 1	ZONE 1	ZONE 1 (AT RAYSOR BRIDGE)		ECPHORA ZONE
	MIDDLE	TORTONIAN OR UPPER VINDOBONIAN	KIRKWOOD FM.	?	ST. MARYS FORMATION, ZONE 2	? ST. MARYS FM. (b)			ARCA ZONE: UPPER PART
				ST. MARYS FORMATION	ZONE 1	?			ARCA ZONE: LOWER PART
				CHOPTANK FM.	CHOPTANK FORMATION				YOLDIA ZONE
				CALVERT FM.	CALVERT FORMATION				SHOAL RIVER FORMATION
									OAK GROVE SAND (f)

[a] The fossiliferous beds in the Pleistocene may or may not be equivalent.
[b] Exposed only at low-water stage.
[c] Beds at Grove Plantation tentatively put in the Waccamaw formation by Cooke may be older.
[d] The species included by Dall in the Myakka River fauna may include some Pleistocene forms.
[e] Position relative to the Caloosahatchee marl not precisely known.
[f] Exact correlation with the Calvert formation not fully established; may be a little older and equivalent to Helvetian.

DISTRIBUTION AND CHARACTERISTICS OF THE PECTINIDAE

Table 2, on pages 174–175, shows the geologic ranges of the Pectinidae in deposits extending in age from medial Miocene (Calvert formation) to the Recent along the Atlantic and Gulf Coastal Plain. Figure 1 on pages 184–185, shows the genetic relationships of the Late Tertiary and Quaternary Pectinidae in the Atlantic and Gulf Coastal Plain. The numbers within the circles in fig. 1 correspond with the numbers before the specific names on Table 2.

In Table 2, the Pectinidae are classified with reference to their generic, subgeneric, and sectional relationships. In the discussions which follow, the subgeneric and sectional names are omitted. The species and varieties are considered with reference to the formations in which they occur, beginning with the Calvert, the oldest formation discussed (see Table 1 above).

TABLE 2.—GEOLOGIC RANGES OF PECTINIDAE

		Stratigraphic position:[a] 1	2	3	4	5
1.[m]	*Pecten (Pecten) humphreysii* Conrad	—	x	—	—	?
1*a*.	*Pecten (Pecten) humphreysii woolmani* Heilprin	x	—	—	—	—
2.	*Pecten (Pecten) smithi* Olsson	—	—	—	—	—
3.	*Pecten (Pecten) macdonaldi* Olsson	—	—	—	—	—
4.	*Pecten (Pecten) leonensis* Mansfield	—	—	—	—	—
4*a*.	*Pecten (Pecten) wendelli* Tucker	—	—	—	—	—
5.	*Pecten (Euvola) ochlockoneënsis* Mansfield	—	—	—	—	—
6.	*Pecten (Euvola) hemicyclicus* Ravenel	—	—	—	—	—
6*a*.	*Pecten (Euvola) brouweri* Tucker	—	—	—	—	—
7.	*Pecten (Euvola) raveneli* Dall	—	—	—	—	—
	Section *Placopecten*					
8.	*Pecten (Chlamys) marylandicus* Wagner	—	?	x	—	—
9.	*Pecten (Chlamys) clintonius rappahannockensis* Mansfield	—	—	—	—	—
10.	*Pecten (Chlamys) clintonius* Say	—	—	—	—	—
11.	*Pecten (Chlamys) decemnarius* Conrad	—	—	—	—	—
12.	*Pecten (Chlamys) virginianus* Conrad	—	—	—	—	—
13.	*Pecten (Chlamys) rogersii* Conrad	—	—	—	—	—
14.	*Pecten (Chlamys) skiptonensis* Mansfield	—	?	—	—	—
	Section *Lyropecten*					
15.	*Pecten (Chlamys) madisonius* Say	x	x	x	—	x
16.	*Pecten (Chlamys) sayanus* Dall	—	?	?	—	—
17.	*Pecten (Chlamys) coccymelus* Dall	—	x	—	—	?
18.	*Pecten (Chlamys) santamaria* Tucker	—	—	—	x	—
19.	*Pecten (Chlamys) santamaria middlesexensis* Mansfield	—	—	—	—	—
20.	*Pecten (Chlamys) jeffersonius* Say	—	—	—	—	—
21.	*Pecten (Chlamys) jeffersonius septenarius* Say	—	—	—	—	—
22.	*Pecten (Chlamys) jeffersonius palmyrensis* Mansfield	—	—	—	—	—
23.	*Pecten (Chlamys) jeffersonius edgecombensis* Conrad	—	—	—	—	—
24.	*Pecten (Chlamys) harrisii* Dall	—	—	—	—	—
25.	*Pecten (Chlamys) exasperatus* Sowerby	—	—	—	—	—
26.	*Pecten (Chlamys) tamiamiensis* Mansfield	—	—	—	—	—
	Section *Plagioctenium*					
27.	*Pecten (Chlamys) eboreus urbannaensis* Mansfield	—	—	—	—	—
28.	*Pecten (Chlamys) eboreus watsonensis* Mansfield	—	—	—	—	—
29.	*Pecten (Chlamys) eboreus yorkensis* Dall	—	—	—	—	—
30.	*Pecten (Chlamys) eboreus eboreus* Conrad	—	—	—	—	—
31.	*Pecten (Chlamys) eboreus darlingtonensis* Dall	—	—	—	—	—
32.	*Pecten (Chlamys) eboreus solaroides* Heilprin	—	—	—	—	—
33.	*Pecten (Chlamys) eboreus senescens* Dall (*f*)	—	—	—	—	—
34.	*Pecten (Chlamys) comparilis* Tuomey and Holmes	—	—	—	—	—
35.	*Pecten (Chlamys) comparilis jacksonensis* Mansfield	—	—	—	—	—
36.	*Pecten (Chlamys) choctawhatcheënsis* Mansfield	—	—	—	—	—
37.	*Pecten (Chlamys) choctawhatcheënsis redbayensis* Mansfield	—	—	—	—	—
38.	*Pecten (Chlamys) evergladensis* Mansfield	—	—	—	—	—
39.	*Pecten (Chlamys) gibbus gibbus* Linné	—	—	—	—	—
40.	*Pecten (Chlamys) gladensis* Mansfield	—	—	—	—	—
41.	*Pecten (Chlamys) gibbus anteamplicostatus* Mansfield	—	—	—	—	—
42.	*Pecten (Chlamys) evergladensis charlottenesis* Mansfield	—	—	—	—	—
43.	*Pecten (Chlamys) gibbus irradians* Lamarck	—	—	—	—	—
44.	*Pecten (Chlamys) charltonius* Mansfield	—	—	—	—	—
	Section *Nodipecten*					
45.	*Pecten (Chlamys) nodosus* Linné	—	—	—	—	—
46.	*Pecten (Chlamys) peedeënsis* Tuomey and Holmes (*k*)	—	—	—	—	—
47.	*Pecten (Chlamys) pontoni* Mansfield	—	—	—	—	—
48.	*Pecten (Chlamys) caloosaensis* Dall	—	—	—	—	—
49.	*Pecten (Chlamys) ernestsmithi* Tucker	—	—	—	—	—
50.	*Pecten (Chlamys) pittieri collierensis* Mansfield	—	—	—	—	—
51.	*Amusium mortoni* Ravenel	—	—	—	—	—
52.	*Amusium (Pseudamussium) cerinum* Conrad	—	x	x	—	—

[a] Pliocene, *fide* Dall. [b] Variety. [c] Specimens small. [d] Specimens large.
[e] At Darlington and Mayesville, South Carolina. [f] *Pecten (Chlamys) eboreus walkerensis* Tucker.
[g] Near Petersburg, Virginia, *fide* Burns. [h] Below Suffolk, Virginia, *fide* Burns.

TABLE 2 (*Continued*)

	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1a.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2.	–	–	–	?	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
4.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–
4a.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
5.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–
6.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
6a.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	–	–	–
7.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[a]	x	–	x	x
8.	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9.	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10.	–	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11.	–	–	–	–	x	x	–	x[b]	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12.	–	–	–	–	x	x	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15.	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18.	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19.	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20.	–	–	–	x	x	–	x	x	x	x	–	–	–	–	x	–	–	x	–	–	–	–	–	–	–	–
21.	–	–	–	–	x	–	–	–	x	–	–	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–
22.	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23.	–	–	–	?	x	x	x	?	x	x	x	–	–	–	?	–	–	–	–	–	–	–	–	–	–	–
24.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
25.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	x	x
26.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
27.	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28.	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–
29.	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30.	–	–	–	–	–	–	x	–	x[c]	x[d]	–	x	x	x	–	x	–	–	–	–	x	–	–	–	–	–
31.	–	–	–	–	–	–	–	x	x	x	x	–	x	–	–	x[e]	–	–	x	–	–	–	–	–	–	–
32.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	x	x	–	–	–
33.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	x	–	–	–	–
34.	–	–	–	–	x[g]	–	x[h]	–	–	–	–	–	–	x	–	x	–	–	x	–	x	–	–	–	–	–
35.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–
36.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
37.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
38.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
39.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[i]	–	x	x
40.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
41.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
42.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
43.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x
44.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[j]	–	–	–
45.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	x	x
46.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
47.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
48.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
49.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x[l]	–	–	–
50.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
51.	–	–	–	–	–	–	x	–	–	–	–	–	x	–	–	x	–	x	x	–	x	–	x	–	–	–
52.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

[i] *Pecten* (*Chlamys*) *dislocatus* Say; submargins smooth.
[j] From Charlton formation; probably Pliocene.
[k] Reported from Darlington district; horizon unknown.
[l] *Fide* Tucker.
[m] The numbers on the left are used in Figure 1 to indicate species.
[n] See list on page 176.

CALVERT FORMATION
(MIDDLE MIOCENE)

Pecten humphreysii Conrad (5*a*) occurs in Maryland in the Fairhaven diatomaceous earth and in the Plum Point marl. In Virginia it probably occurs in the Calvert formation, but I have not seen specimens from there. The species has been reported from South Carolina without a definite locality assignment, and its occurrence there is questionable. It appears to be confined to the Calvert formation in Maryland. Grant and Gale (14*a*) placed *Pecten humphreysii* Conrad in synonymy with *P. laqueatus* Sowerby, a living species in the Japan Sea. Although the two forms belong to the same group they are not specifically identical.

Pecten humphreysii woolmani Heilprin (16*a*) occurs in the marls of Jerico (Kirkwood formation), New Jersey. The containing bed is equivalent in age to some part of the Calvert formation of Maryland. The subspecies differs from *P. humphreysii* Conrad in having a more sharply striated surface and more quadrate ribs on the convex valve.

Glenn (13*a*) reported *Pecten marylandicus* Wagner (41*a*) from the Calvert formation in a railway cutting at White's Landing, near Friendship, Maryland, and from several localities in the Choptank formation. I have not seen the specimens identified by him from White's Landing. A few small specimens in the U. S. National Museum, from Plum Point, Calvert County, are close to *P. marylandicus*, but are not identical. The shells from the Choptank formation that have been referred to *P. marylandicus* are doubtless descendants of the Calvert form.

In Maryland and Virginia *Pecten madisonius* Say (30*a*) is believed to be confined to the Calvert and Choptank formations. In New Jersey it occurs in the Kirkwood formation. The reference by Conrad and others to its occurrence at Urbanna and near City Point, Virginia, is incorrect, as another species occurs at these localities. *P. madisonius* is related to *Pecten acanikos* Gardner, the holotype of which, a left valve, came from Boynton Landing, Choc-

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List of Stratigraphic Positions Indicated in Table 2

Miocene, 1–24:
New Jersey: *1*, Kirkwood formation.
Maryland: *2*, Calvert formation; *3*, Choptank formation; *4*, St. Marys formation.
Virginia: *5*, Calvert formation; *6*, Choptank formation; *7*, St. Marys formation, zone 1; *8*, same, zone 2; *9*, Yorktown formation, zone 1; *10*, same, zone 2, *Chama*-bearing bed; *11*, same, zone 2, exposures at Yorktown; *12*, same, zone 2, exposures at Suffolk.
North Carolina, northern part: *13*, Yorktown formation, zone 1; *14*, same, zone 2, equivalent of *Chama*-bearing bed; *15*, same, probable equivalent of zone 2, beds at Yorktown, Virginia; *16*, same, probable equivalent of zone 2, beds at Suffolk, Virginia; *17*, same, zone 2, equivalent of beds at Suffolk, Virginia, or younger.
North Carolina, southern part: *18*, Duplin marl.
Georgia: *19*, Duplin marl, upper bed at Porters Landing.
South Carolina: *20*, Yorktown formation, zone 1, Raysors Bridge; *21*, Duplin marl.
Florida: *22*, Choctawhatchee formation, *Arca* zone; *23*, same, *Ecphora* zone; *24*, same, *Cancellaria zone*. (The *Yoldia* zone and Aluminous clay are omitted.)
Pliocene, 25–29.
North Carolina: *25*, Waccamaw formation.
South Carolina: *26*, Exposures at the Grove Plantation; *27*, Waccamaw formation.
Florida: *28*, Caloosahatchee marl; *29*, limestones of Tamiami Trail.
Pleistocene, 30.
Recent, 31.

tawhatchee River, Florida. The principal differences between the two species are that *P. acanikos* has a more inflated shell and wider and more finely striated submargins.

Two fragments of shells, one collected from the Plum Point marl (Calvert formation) and the other from the Choptank formation near Greensboro, Maryland, closely resemble *P. sayanus* Dall (9*a*), a species confined to the Oak Grove sand of the Alum Bluff group of Florida.

The holotype of *Pecten coccymelus* Dall (9*b*) may be an immature specimen representing a varietal form of *P. madisonius*. The species, so far as known, occurs only in the Plum Point marl member of the Calvert formation of Maryland.

Glenn (13*b*) records *Amusium cerinum* Conrad (7*a*) from zone 17 of the Choptank formation and from the Calvert formation at Plum Point, Maryland. Dall (9*c*) records this species from the Ashley River phosphate rock of South Carolina, but I am unable to confirm this occurrence.

CHOPTANK FORMATION (MIDDLE MIOCENE)

Pecten madisonius Say and *Amusium cerinum* Conrad, occur in both the Calvert and Choptank formations. *Pecten marylandicus* Wagner questionably occurs in the Calvert formation, but is found in the Choptank formation at several localities in Maryland and Virginia.

Pecten skiptonensis Mansfield, n.sp. (p. 186), was collected near Skipton, Talbot County, Maryland. It may have come from the Choptank formation, but its exact horizon is questioned.

ST. MARYS FORMATION (UPPERMOST MIDDLE MIOCENE)

In Maryland *Pecten santamaria* Tucker (39*a*) is confined to the St. Marys formation. In Virginia it occurs in the *Bulliopsis quadrata* zone (zone 1), of the St. Marys formation.

Miss Tucker reports this species from Snow Hill, Green County, North Carolina. The only *Pecten* I have seen from this locality was a right valve collected by T. W. Stanton from a bed overlying the Cretaceous on Contentnea Creek in the western end of the village. This specimen belongs to *Pecten eboreus eboreus* Conrad, a late Yorktown species and not a St. Marys species.

Pecten santamaria middlesexensis Mansfield, n. subsp., (p. 187) occurs in the uppermost part of the St. Marys formation (zone 2) of Virginia. It is a descendant of *P. santamaria* Tucker and differs but slightly from it. The right valve is more inflated, the ears are relatively larger, and the byssal notch shallower than on the corresponding valve of *P. santamaria*.

Pecten eboreus urbannaensis Mansfield (19*b*) occurs in the highest fossiliferous zone (zone 2) of the St. Marys formation of Virginia. This subspecies probably is the ancestor of *Pecten eboreus eboreus* Conrad.

Pecten clintonius rappahannockensis Mansfield, n. subsp. (p. 186), occurs in the *Crassatellites meridion-*

alis zone (zone 2) of the St. Marys formation of Virginia. It is considered the ancestral form of *Pecten clintonius* Say.

YORKTOWN FORMATION AND THE DUPLIN MARL (UPPER MIOCENE)

The holotype and paratype of *Pecten smithi* Olsson (25*a*) came from Kings Mill, James River, Virginia. The position in the bluff at this locality is not given but the specimens probably came from the lower bed (zone 1) of the Yorktown formation. A fairly well preserved upper valve of this species was collected at this locality (U.S.G.S. Sta. 2452) by the late Frank Burns. Matrix attached to this specimen suggests that it came from the lower bed. I have not seen the species outside of its type locality.

One right valve of *Pecten clintonius* Say (30*b*) in the U. S. National Museum is labelled by Doctor Foreman, the collector, as from Maryland. No one else has collected this species from that state. The type locality is unknown and its occurrence in Maryland is questionable. I have tentatively assigned the specimens collected from the lower bed at the locality below Old Kings Mill Wharf, James River, to *P. clintonius* Say. This species is confined to zone 1 of the Yorktown formation in Virginia and North Carolina.

Pecten decemnarius Conrad (3*a*) and *Pecten virginianus* Conrad (4*a*) are closely related and usually occur together. Both are common species in the *Chama*-bearing bed (basal part of zone 2 of the Yorktown formation) on the James River below old Kings Mill Wharf, and they also occur in the bed below the fragmental series at Yorktown, Virginia. They may be present in zone 1 of the Yorktown formation.

Conrad in 1840 gives the locality of *Pecten rogersii* Conrad (3*a*; 4*b*) as "James River, near Smithfield, Va." Glenn (13*c*) assigned a shell from near Skipton, Maryland, to this species and questionably referred it to the Choptank formation. The Maryland form is now considered a different species. The species usually occurs in the same bed with *P. decemnarius* Conrad and *P. virginianus* Conrad. I have collected specimens from the *Chama*-bearing bed (lower part of zone 2) of the Yorktown formation in Virginia and North Carolina.

Pecten jeffersonius Say (30*c*) occurs in zone 1 of the Yorktown formation, in the *Chama*-bearing bed (basal part of zone 2) and in the highest part of zone 2 (in the vicinity of Suffolk, Virginia). The form in zone 1, usually has 10 or 11 ribs and the form at Suffolk 7 or 8 ribs. I once considered the specimens from the vicinity of Suffolk as representing a subspecies, but I find specimens in zone 1 with as few ribs as those from the Suffolk locality and consequently am unable to separate them subspecifically. In North Carolina the species occurs in beds of the same age as those in Virginia. In South Carolina the species occurs at Raysors Bridge, and in Florida in the *Ecphora* zone.

Grant and Gale (14*b*) placed *P. magnolia* Conrad in synonymy with *P. jeffersonius* Say. Although the two forms show considerable similarity in size and strength of ribs there appear to be sufficient differences to justify treating them as distinct species. *P. jeffersonius* is nearly equilateral, with ribs of nearly equal strength, diminishing only slightly toward the margin; whereas *P. magnolia* is inequilateral, with very strong and wide ribs medially and much weaker ribs near the submargins.

The occurrence of *Pecten jeffersonius septenarius* Say (30*d*) is questionably assigned by Glenn (13*d*) to Maryland. In Virginia and North Carolina the variety appears to be confined to the *Chama*-bearing bed (basal part of zone 2, Yorktown). In Georgia it occurs in the upper bed at Porter's Landing, Savannah River, and in Florida in the *Ecphora* zone.

Pecten jeffersonius palmyrensis Mansfield, n. subsp. (p. 187), is very large and has four very wide ribs. It occurs in the lowest Miocene bed at Palmyra Bluff, Roanoke River, North Carolina. The horizon is assigned to the *Chama*-bearing bed, lower part of zone 2, of the Yorktown formation.

Pecten jeffersonius edgecombensis Conrad (6*a*) is known to appear in the *Chama*-bearing bed (lower part of zone 2 of the Yorktown formation) in the section below Old Kings Mill Wharf, James River, Virginia, It is a common fossil at Yorktown and at Suffolk, Virginia. In North Carolina it occurs at the same horizon as in Virginia. It questionably occurs in zone 1 of the Yorktown formation in both Virginia and North Carolina. In South Carolina it questionably occurs at Raysors bridge, Edisto River. The subspecies probably does not occur in the St. Marys formation of Maryland. The specimen figured by Glenn (13*e*) came from Edgecombe County, North Carolina, and not from St. Marys, Maryland, as reported.

Pecten eboreus yorkensis Dall (9*d*), which does not appear to have been figured, came from some part of the fragmental series at Yorktown, Virginia. Much larger specimens were collected below Yorktown by Dr. Julia Gardner and me in 1933 from a laminated sandy clay bed which filled a channel formed in the surrounding fragmental series. The subspecies also occurs in a bluish clayey sand in the lowest bed at old Rock Wharf, James River (U. S. Geol. Survey Station 1/206). It appears to occur in the middle part of zone 2 of the Yorktown formation. *Pecten eboreus yorkensis* probably is the precursor of *P. eboreus eboreus* Conrad, differing from the latter in having a shell more inflated in the umbonal region.

The type locality of *Pecten eboreus watsonensis* Mansfield, n. subsp., (p. 188) is at station 1/962, old road to Watson's Landing, about 2 miles north of Alum Bluff, Liberty County, Florida. This form was referred to *P. eboreus eboreus* Conrad by me (23*b*). The subspecies also occurs in zone 1 of the Yorktown formation at several localities in Virginia.

The type locality of *Pecten eboreus eboreus* Conrad (2*a*) is Suffolk, Virginia. In Virginia this subspecies occurs sparingly in the middle part of zone 2 of the Yorktown formation and abundantly in the upper part of this zone. I have not seen it in the Yorktown formation at Yorktown, but elsewhere it occurs in beds that are at about the same horizon as the fragmental series. In North Carolina small specimens, probably of this subspecies, occur in the *Chama*-bearing bed, but larger specimens are found in later beds. The subspecies occurs in the Duplin marl of both North and South Carolina and in the Pliocene at the Grove Plantation, South Carolina. I have seen only the left valve of specimens in the fauna at Goose Creek. These may prove to be another subspecies of *eboreus*, but they are not the subspecies *solaroides* Heilprin, a characteristic Pliocene form from the Caloosahatchee marl.

The typical form of *Pecten eboreus darlingtonensis* Dall (9*e*) occurs in the Duplin marl as developed in the vicinity of Darlington, South Carolina. It occurs also in the Duplin marl at Muldrow place, Sumter County, South Carolina. Specimens that occur in the northern part of North Carolina in deposits that range in horizon from zone 1 of the Yorktown formation to the beds in the vicinity of Suffolk, Virginia, appear more closely related to *P. eboreus darlingtonensis* than to any other subspecies. As a rule these specimens have less squarely cut ribs than *darlingtonensis*. Compared with *P. eboreus watsonensis*, a new subspecies from zone 1, Yorktown formation, they have less widely spaced ribs. The specimens from zone 1 of the Yorktown formation perhaps should be regarded as an intermediate form between *P. eboreus watsonensis* and *P. e. darlingtonensis*, but I have tentatively placed them with the latter. In Florida this subspecies occurs in the *Cancellaria* zone of the Choctawhatchee formation.

The recorded distribution of *Pecten comparilis* Tuomey and Holmes (40*a*) is as follows: Yorktown formation at Petersburg and 16 miles below Suffolk, Nansemond River, Virginia, one specimen in the U. S. National Museum collected by the late Frank Burns from each locality; upper Miocene at Darlington, South Carolina (Tuomey and Holmes); Pliocene at Goose Creek, South Carolina; upper Miocene bed at Porters Landing on the Savannah River, Georgia; and upper Miocene (*Cancellaria* zone), Florida.

Amusium mortoni (Ravenel) (29) occurs in the Miocene in the highest zone of the Yorktown formation in Virginia, in the Duplin marl of the Carolinas, and in the Choctawhatchee formation of Florida (*Ecphora* zone and *Cancellaria* zone). It occurs in the Pliocene of South Carolina at the Grove Plantation, and in the Pliocene of Florida.

Tuomey and Holmes recorded *Pecten peedeënsis* Tuomey and Holmes (40*b*) from Peedee River, Darlington District, South Carolina. Two specimens (probably left valves) in the U. S. National Museum (No. 9526), labelled *P. peedeënsis*, were collected

from the Peedee River in the Darlington district. The exact locality and horizon of the species is unknown. It may have come from the upper Miocene (Duplin marl), but the matrix on the specimens is unlike that of the Duplin marl.

CHOCTAWHATCHEE FORMATION OF FLORIDA (UPPER MIDDLE MIOCENE AND UPPER MIOCENE)

Pecten macdonaldi Olsson (27*a*) was reported by me (23*c*) from the Choctawhatchee formation (*Arca* zone), upper middle Miocene of Florida.

Pecten ochlockoneënsis Mansfield (23*d*) occurs in both the *Ecphora* and *Cancellaria* zones (upper Miocene) of the Choctawhatchee formation of Florida.

Pecten leonensis Mansfield (23*e*) occurs in the *Ecphora* zone (upper Miocene) of the Choctawhatchee formation of Florida. Related species occur in the upper Miocene bed at Porters Landing, Savannah River, Georgia, and at Raysors Bridge, Edisto River, South Carolina.

Pecten pontoni Mansfield (23*f*) was first assigned to the section *Lyropecten*, but I now think it may be more closely related to the section *Nodipecten*, to which I have tentatively assigned it. This species occurs in the *Arca* zone (upper middle Miocene) of Florida.

Pecten eboreus watsonensis Mansfield, n. subsp., previously mentioned in this paper, was called *Pecten eboreus eboreus* by me in an earlier paper (23*g*). In Florida it occurs in the *Ecphora* zone (upper Miocene).

Pecten comparilis Tuomey and Holmes, also previously mentioned in this paper, occurs only in the *Cancellaria* zone (uppermost Miocene) of Florida.

Pecten comparilis jacksonensis Mansfield (23*h*) is recorded from the *Ecphora* zone (upper Miocene) of Florida.

Pecten choctawhatcheënsis Mansfield (23*i*) which is restricted to the *Arca* zone (upper middle Miocene) of Florida, is closely related to *P. levicostatus* Toula from the Gatun formation of Panama.

Pecten choctawhatcheënsis redbayensis Mansfield (23*j*) occurs in the same bed with *P. choctawhatcheënsis* and it is similar to it in most features, differing from the latter in having a less inflated shell and fewer, more widely spaced, and more distinct ribs.

Pecten jeffersonius Say, which has been mentioned before in this paper, occurs in the *Ecphora* zone (upper Miocene) in Florida.

Pecten eboreus darlingtonensis Dall, also previously mentioned, occurs in Florida throughout the *Cancellaria* zone (upper Miocene).

PLIOCENE

The type locality of *Pecten hemicyclicus* Ravenel (40*c*) is the Grove Plantation, Cooper River, South Carolina. A nearly perfect specimen from the Smith place (Yeaman's Hall) on Goose Creek is in the U. S. National Museum. The species occurs at "The Dividers," 2 miles above the Charleston and Savannah River Railway at Pon Pon Station, Colle-

ton County, South Carolina. It differs from *P. raveneli* Dall, a species from the Pliocene Caloosahatchee marl, in having a much larger shell.

The holotype of *Pecten raveneli* Dall (9*f*), a right valve (U. S. Nat. Mus. 107750), came from the Pliocene Caloosahatchee marl. The species is living in the present seas from North Carolina to the Gulf of Mexico and West Indies.

The holotype of *Pecten harrisii* Dall (9*g*), a right valve (U. S. Nat. Mus. 154485), came from the Pliocene Caloosahatchee marl of Florida. This species appears to be confined to the Pliocene.

Pecten exasperatus Sowerby (33*a*) ranges through the Pliocene, Pleistocene, and Recent. Its geographic range in the Recent seas is from Cape Hatteras, North Carolina, southward to the West Indies.

Pecten tamiamiensis Mansfield (22*a*) is slightly more inflated than *P. interlineatus* Gabb, and probably represents a distinct species. The latter is a fossil species from Santo Domingo; the holotype, a small right valve in the collection at the Academy of Natural Sciences of Philadelphia, has its anterior ear nearly broken away, so that its relationship to a larger shell is difficult to determine.

The holotype of *Pecten eboreus senescens* Dall (9*h*), a right valve, is from the Pliocene Waccamaw formation of South Carolina. The shell of the holotype is very thin, with about 23 obscure ribs, which, however, are more distinct on the inner surface. Both valves are oblique, the left one being slightly more inflated than the right. "*Chlamys*" *eboreus walkerensis* Tucker (39*ab*) is a synonym of *P. eboreus senescens* Dall.

Pecten eboreus solaroides Heilprin (15*a*) was described from the Pliocene Caloosahatchee marl of Florida. It differs from *P. eboreus eboreus* in having a squarer and more distant ribs, interradial striae, and finer concentric sculpture. It also occurs in the Pliocene of the Carolinas.

Pecten gibbus gibbus Linnaeus (*P. dislocatus* Say (17*a*) ranges in time from the Pliocene to the Recent. According to Dall, it ranges in the Recent seas from Cape Hatteras southward to Cape St. Roque in northeastern Brazil. Most of the Pleistocene and Recent shells referred to *P. gibbus gibbus* have radial sculpture on the submargins, but the Pliocene specimens have smooth submargins and usually can be separated by this feature.

Pecten gibbus anteamplicostatus Mansfield, n. subsp. (p. 189) differs from the Recent species, *Pecten gibbus amplicostatus* Dall, mainly in having smooth instead of radially striate submargins. It appears to be confined to the Pliocene.

Pecten (*Plagioctenium*) *gladensis* Mansfield, n.sp. (p. 188), may prove to be a subspecies of *Pecten gibbus*. It was collected from the Pliocene limestone of southern Florida.

Pecten evergladensis Mansfield (22*b*) occurs in limestone of Pliocene age in southern Florida. Specimens in the Pliocene Caloosahatchee marl were at first considered as belonging to this species, but I now think that

they belong to a new subspecies. Though closely related to the Caloosahatchee form it differs in having less squarely cut ribs and less closely spaced concentric sculpture.

Pecten evergladensis charlottensis Mansfield, n. subsp. (p. 189), is closely related to *P. evergladensis*, but differs in having squarer ribs and more closely spaced concentric sculpture. The new subspecies occurs in the Pliocene Caloosahatchee marl at Shell Creek and on Caloosahatchee River and possibly on Alligator Creek.

Pecten pittieri collierensis Mansfield (22*c*) occurs in Pliocene limestone of southern Florida.

Pecten caloosaensis Dall (9*i*), from the Pliocene of Caloosahatchee River and Shell Creek, is a characteristic Pliocene species.

The type locality of *Pecten ernestsmithi* Tucker (36*a*) is Keith's marl pit, Neills Eddy Landing, Cape Fear River, North Carolina. Tucker and Wilson (39*a*) report the species from the Philocene Caloosahatchee marl of Florida.

Pecten brouweri Tucker (39*ac*) occurs in the Pliocene Waccamaw formation at Walkers Bluff, North Carolina (type locality), and at Nixons Landing on the Waccamaw River, South Carolina. This species is closely related to both *P. raveneli* Dall and *P. hemicyclicus* Ravenel; to which one of these species it is more closely related I am uncertain.

Pecten wendelli Tucker (39*Ad*) occurs in the Caloosahatchee Pliocene at Fort Denaud, Florida (type locality). Specimens in the U. S. National Museum collection from the Pliocene along the Caloosahatchee River and at Shell Creek, Florida, agree with the illustration of the holotype of this species.

Chlamys eboreus walkerensis Tucker (39*Ae*) reported in the Waccamaw Pliocene at Walkers Bluff, North Carolina (type locality), and at Nixons Landing on the Waccamaw River, South Carolina, is an adult form of *Pecten eboreus senescens* Dall.

Pecten nodosus Linnaeus (17*b*) occurs in the Pliocene Caloosahatchee marl, in the Pleistocene of the Antilles, and is living in the Gulf of Mexico and the Antilles.

PLEISTOCENE

A few species that occur in the Pleistocene have been mentioned in this paper.

The species identified by Dall (9*j*) from North Creek, near Osprey, are: *Pecten gibbus* var. *dislocatus* Say and *Pecten gibbus irradians* Lamarck. The specimens referred to *P. gibbus dislocatus* (=*gibbus gibbus* Linné) have rather strong radials on the submargins. In this feature they more closely resemble the Recent specimens from Florida than the specimens from the Pliocene Caloosahatchee marl.

The specimen (a left valve) identified as *P. gibbus irradians* (U. S. Nat. Mus. 154182) has 19 ribs. The normal number of ribs on the Recent specimens of *P. gibbus irradians* is 18 to 20, and on *P. gibbus borealis* (the northern form) 16 to 18 ribs. The specimen from North Creek is a little larger than most specimens of *P. gibbus irradians* but in other features is similar to it.

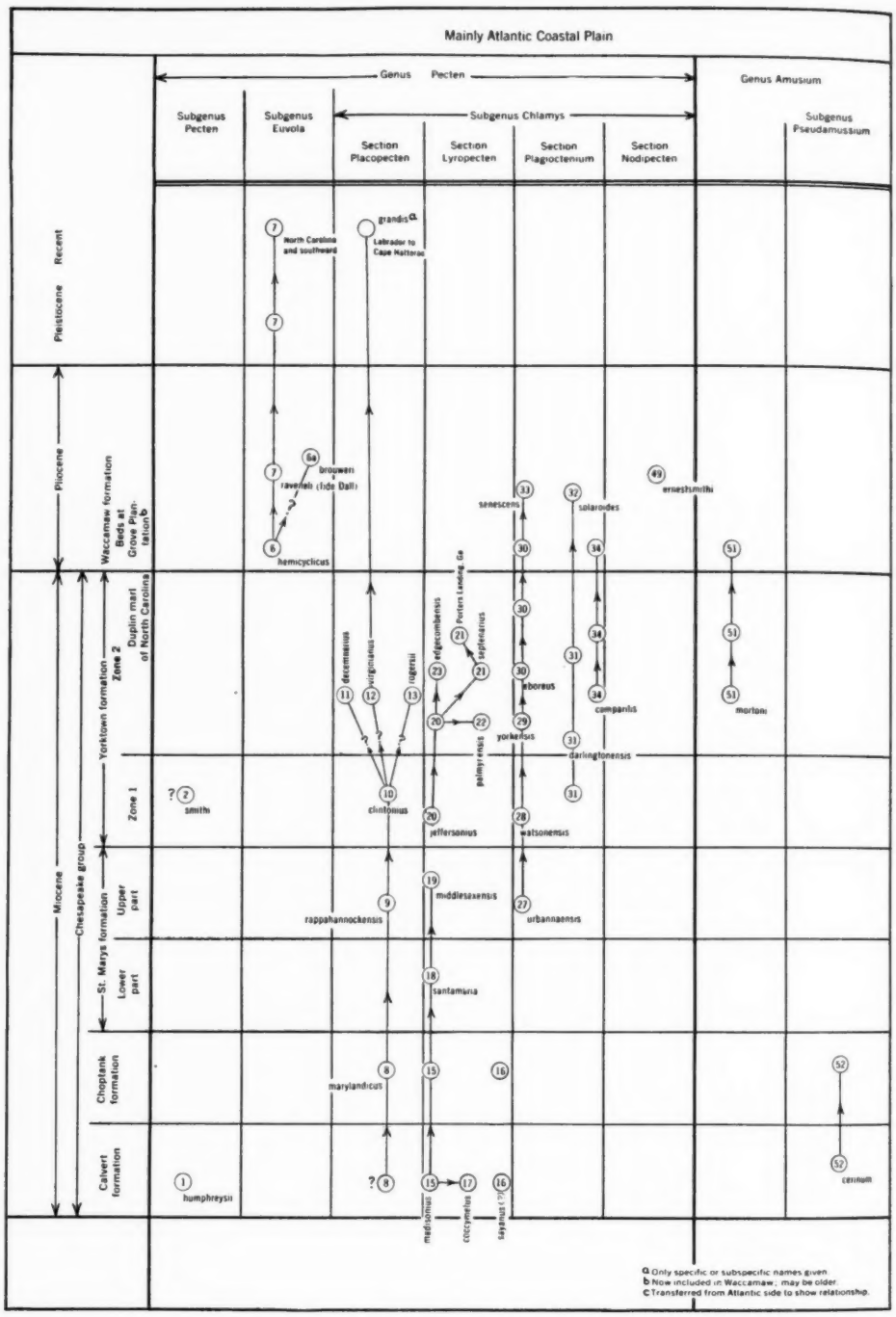
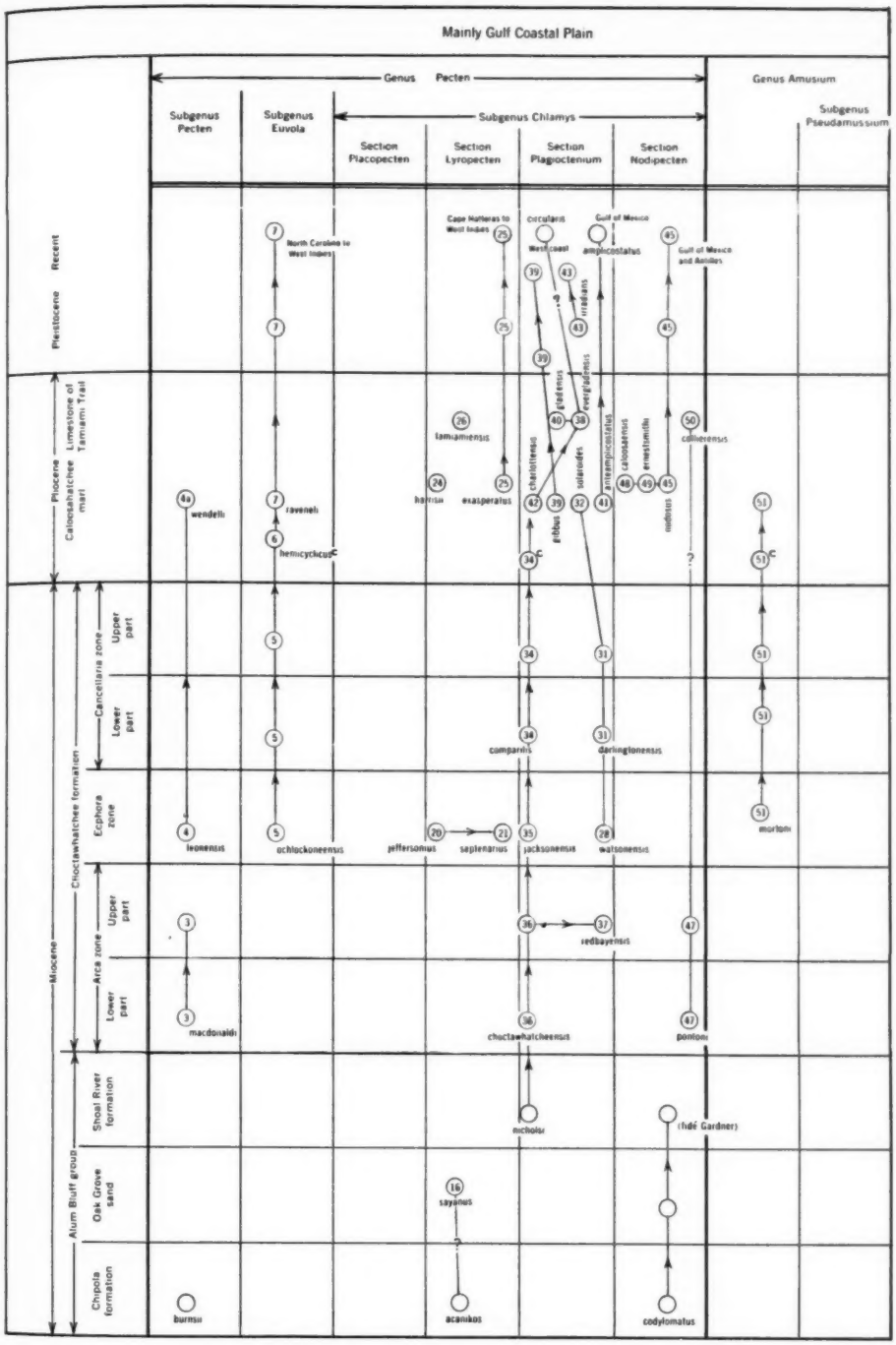


FIG. 1.—Genetic relationships of the Late Tertiary and



Quaternary Pectinidae in the Atlantic and Gulf Coastal Plain.

NEW TERTIARY PECTENS FROM THE ATLANTIC AND GULF COASTAL PLAINS

The new species and subspecies described below will add materially to the usefulness of the group in determining the stratigraphic relationships of their containing beds. The types are deposited in the U. S. National Museum.

The photographs used for the illustrations were made by Mr. Nelson W. Shupe and the prints were retouched by Miss Frances Wieser.

Genus PECTEN Müller, 1776
Subgenus CHLAMYS Bolten, 1778
Section PLACOPECTEN Verrill, 1897

PECTEN (CHLAMYS) SKIPTONENSIS Mansfield, n. sp.

Plate 23, figure 12

Pecten (Nodipecten) rogersi Conrad (part)· DALL, *1898*, Wagner Free Inst. Sci., Trans. vol. 3, pt. 4, p. 730.
Pecten (Chlamys) rogersi GLENN (not Conrad, 1834), *1904*, Maryland Geol. Survey, Miocene, pl. 99, fig. 4.

Shell small, nearly equilateral, compressed but not flat. Right anterior auricle with a deep byssal sinus and sculptured with four fine radial threads over the surface between the dorsal margin and the byssal area. Byssal area crossed with fine threads which surmount a rather strong thread parallel with and adjacent to the submargin. Posterior ear marked with four weak radials. Disk sculptured with six ribs, the anterior and posterior weak, others much wider, equally and widely spaced. Faint growth lamellae ornament the ribs and interspaces. Obscure subradials visible only at the distal ends of the ribs, none observed between them. The ctenolium provided with fine short spines.

Dimensions of holotype: Right valve (U. S. Nat. Mus. 143658), length, 8.5 mm.; height, 10 mm.; convexity 1.6 mm.

Pecten (Chlamys) skiptonensis differs from *P. (C.) rogersi* Conrad in lacking strong radial sculpture over the whole shell.

Type locality: Station 2366, near Skipton, Talbot County, Maryland.

Horizon: Choptank formation(?)

PECTEN (CHLAMYS) CLINTONIUS RAPPAHANNOCKENSIS Mansfield, n. subsp.

Plate 22, figures 1–3

Pecten (Chlamys) clintonius Say (30*b*) was reported to have come from Maryland. One right valve deposited in the collection of the U. S. National Museum and identified as *Pecten clintonius* Say is labelled, on the authority of Doctor Foreman, as collected from Maryland. No one else has reported this species from Maryland. The type locality of *Pecten clintonius* is unknown, and its occurrence in Maryland is questionable. Say's type as figured bears close resemblance to specimens occurring in the lower bed below Old Kings Mill Wharf on the north shore of the James River, Virginia, and that may be in reality the type locality of the species. I was unable to find the holotype of *P. clintonius* in the collection of the Academy of Natural Sciences of Philadelphia.

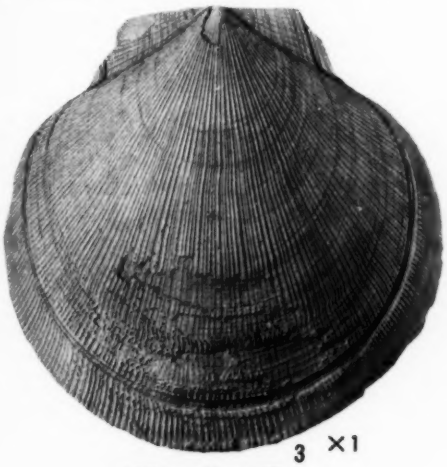
A number of specimens of the subgenus *Chlamys*, collected from the basal bed at Jones Point, right bank of the

EXPLANATION OF PLATE 22

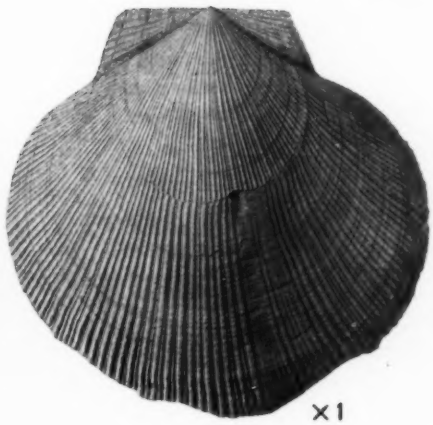
FIGS. *1, 2, 3—Pecten (Chlamys) clintonius rappahannockensis* Mansfield, n. subsp. *1, 2*, Right and left valves, syntypes, ×1½, U. S. Nat. Mus. 373072; *3*, left valve, paratype, ×1, U. S. Nat. Mus. 111992. (p. 186)

4—Pecten (Chlamys) clintonius Say, a left valve, ×1, U. S. Nat. Mus. 495174; collected at station 11789, lower bed below Old Kings Mill Wharf on the north shore of James River, Virginia. Specimen figured to show the coarser radial sculpture, in comparison with fig. 3, though a smaller specimen. (p. 178)

5, 6—Pecten (Chlamys) santamaria middlesexensis Mansfield, n. subsp., syntypes, ×1½, U. S. Nat. Mus. 373074; *5*, left valve; *6*, right valve. (p. 187)

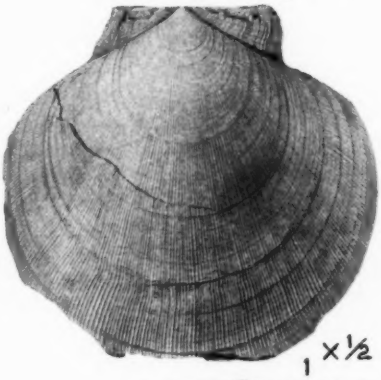


3 ×1

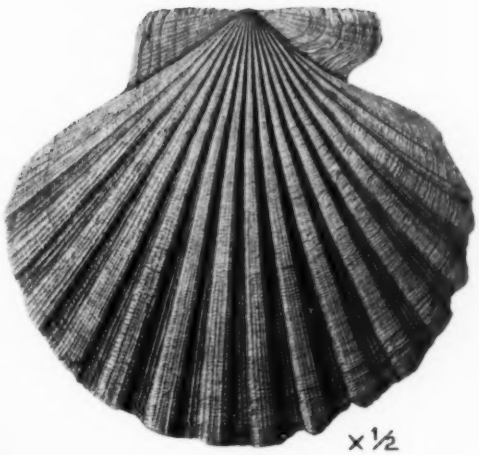


×1

4

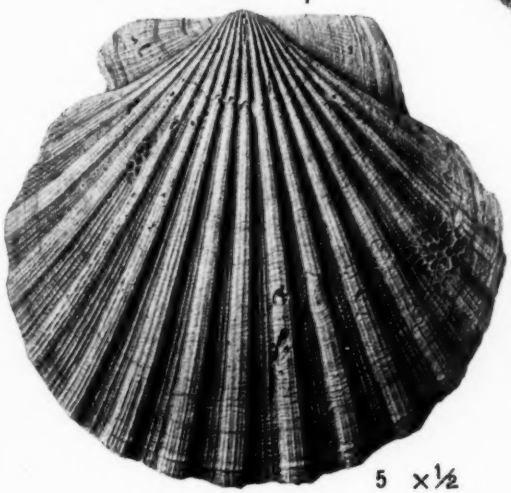


1 ×½

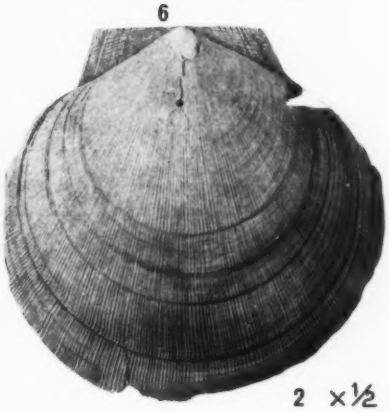


×½

6



5 ×½



2 ×½

Mansfield, Tertiary Pectens

UNIV. OF MICH.

Rappahannock River, Virginia, are not identical with the specimens tentatively referred to *Pecten clintonius* from the James River locality, and are here referred to a new subspecies, *rappahannockensis*. The following is a description of the new subspecies:

Shell large, thin and fragile, slightly inequilateral, weakly inflated, the left valve more so than the right. Hinge line rather short. Ears nearly equal in size; right anterior with a very shallow notch. Ears marked with 7 to 9 weak, finely crenulated radials. Surface of both valves similarly sculptured with many (about 10 to a centimeter) nearly flat radials. Some of the single radials on the early part of the valves divide into two radials distally, and a single radial may come in between the divided pair. Intercostal spaces concentrically crossed by fine diagonal lines.

Dimension of larger syntypes (U. S. Nat. Mus. 373072): Left valve, length 115 mm.; height, 111 mm.; convexity, 19 mm. Right valve (margins not entire), length, over 114 mm.; height, over 106 mm.; convexity, 12 mm.

Pecten clintonius rappahannockensis differs from specimens collected from the lower bed below Old Kings Mill Wharf, and referred here to *P. clintonius*, s.s., in having more uniform and more closely spaced radials and a longer hinge line.

Type locality: Station 3924, Jones Point, right bank of Rappahannock River, Essex County, Virginia; Collected by the late Frank Burns.

Horizon: St. Marys formation, zone 2 (*Crassatellites meridionalis* zone).

Occurrence: Common at the type locality; a large corroded right valve, Station 1/536, lower bed half way between Coggins Point and Indian Point, right bank of the James River, may belong to the new subspecies; specimens collected from Coggins Point, James River, Virginia, by Angelo Heilprin, appear closely related.

Section LYROPECTEN Conrad, 1863

PECTEN (CHLAMYS) SANTAMARIA MIDDLESEXENSIS Mansfield, n. subsp.

Plate 22, figures 5, 6

Pecten santamaria middlesexensis is like *santamaria* Tucker, s.s., in its major features, but differs in the following minor features. Right valve slightly more inflated, the ears relatively wider, the byssal notch shallower, the ribs less rounded distally; left valve with less rounded ribs distally and coarser subradials on the ribs. The new subspecies is a descendant of *P. santamaria*.

Dimensions of syntypes (U. S. Nat. Mus. 373074): Right valve, length, 140 mm.; height, 130 mm.; convexity, 18 mm. Left valve, length, 154 mm.; height, 140 mm.; convexity, 30 mm.

The specimens figured by me (19*c*) as *Pecten madisonius* Say variety, have shallower channels between the ribs than the syntypes of *P. santamaria middlesexensis*, but in other features are the same and are considered only mutations of this subspecies. However, these specimens occur in the highest beds of the St. Marys formation of Virginia.

Type locality: Station 3915, Urbanna, Middlesex County, Virginia.

Horizon: St. Marys formation, zone 2 (*Crassatellites meridionalis* zone).

PECTEN (CHLAMYS) JEFFERSONIUS PALMYRENSIS Mansfield, n. subsp.

Plate 23, figure 3

Shell large, ovate, equilateral, moderately inflated. Ribs four in number, high, very wide, nearly flat on the upper surface, and undercut over the umbonal area but rounded distally. Whole surface radially sculptured with many rounded, scabrous, coarse threads.

Dimensions of holotype: Right valve (U. S. Nat. Mus. 373075), length 155 mm.; height, 146 mm.; convexity 30 mm.

Type locality: Station 1/1218, lowest Miocene bed at Palmyra Bluff, right

bank of Roanoke River, Halifax County, North Carolina. W. C. Mansfield and Willis P. Popenoe, collectors.

Horizon: Upper Miocene, *Chama*-bearing bed, lower part of zone 2 of the Yorktown formation.

Pecten jeffersonius palmyrensis differs from *P. jeffersonius septenarius* Say in having fewer ribs.

Section PLAGIOCTENIUM Dall, 1898

PECTEN (CHLAMYS) EBOREUS WATSONENSIS Mansfield, n. subsp.

Plate 23, figures 1, 2

Pecten eboreus DALL (not *P. eboreus eboreus* Conrad), *1903*, Wagner Free Inst. Sci., Trans., vol. 3, pt. 6, p. 1597.

Chlamys (*Plagioctenium*) *eboreus eboreus* MANSFIELD (not *P. eboreus eboreus* Conrad), *1932*, Florida Geol. Survey, Bull. 8, p. 60, pl. 12, fig. 11.

Shell rather large, ovate, slightly inequilateral, the posterior region being more produced and moderately inflated, the left valve slightly more so than the right. Ears rather large; right anterior with a shallow byssal notch and ornamented with 4 weak radials and fine concentric lamellae; left posterior ear with about 6 radials. Both valves sculptured with 18 nearly flat, nearly smooth, moderately narrow ribs separated by spaces about as wide as ribs. Both ribs and interspaces sculptured with coarse concentric imbricated lamellae.

Dimensions: Holotype, right valve (U. S. Nat. Mus. 371139), length, 80 mm.; height, 74 mm.; convexity, 17 mm. Paratype, left valve (U. S. Nat. Mus. 373076), length 100 mm.; height, 94 mm.; convexity, 22 mm.

Pecten eboreus watsonensis differs from *P. eboreus eboreus* Conrad in having 5 to 8 fewer, more widely spaced ribs.

Type locality: Station 1/962, old road to Watsons Landing, about 2 miles north of Alum Bluff and about the same distance from Apalachicola River, Liberty County, Florida (sec. 1, T. 1 N., R. 8 W.). Base of bed about 80 feet above the river terrace.

Occurrence: Florida; confined to the *Ecphora* zone at a number of localities. Virginia; zone 1, of the Yorktown formation at Station 1/539, Schmidts Bluff (upper bed), right bank of the James river, Surry County, W. C. Mansfield, collector. Station 1/486 *b*, highest fossiliferous bed one-third mile below Lanexa, New Kent County, W. C. Mansfield collector. Station 12902, College Park, one mile west-southwest of Williamsburg, on road to Jamestown. Julia Gardner, and others, collectors.

PECTEN (CHLAMYS) GLADENSIS Mansfield, n. sp.

Plate 23, figure 4

Shell large, rather thick, nearly equilateral, longer than high. Ears subequal, slightly concave, sculptured mainly with

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EXPLANATION OF PLATE 23

FIGS. *1, 2—Pecten* (*Chlamys*) *eboreus watsonensis* Mansfield, n. subsp., ×½. *1*, Paratype, left valve, U. S. Nat. Mus. 373076; *2*, holotype, right valve, U. S. Nat. Mus. 371139. (p. 188)

3—Pecten (*Chlamys*) *jeffersonius palmyrensis* Mansfield, n. subsp., holotype, right valve, ×½, U. S. Nat. Mus. 373075. (p. 187)

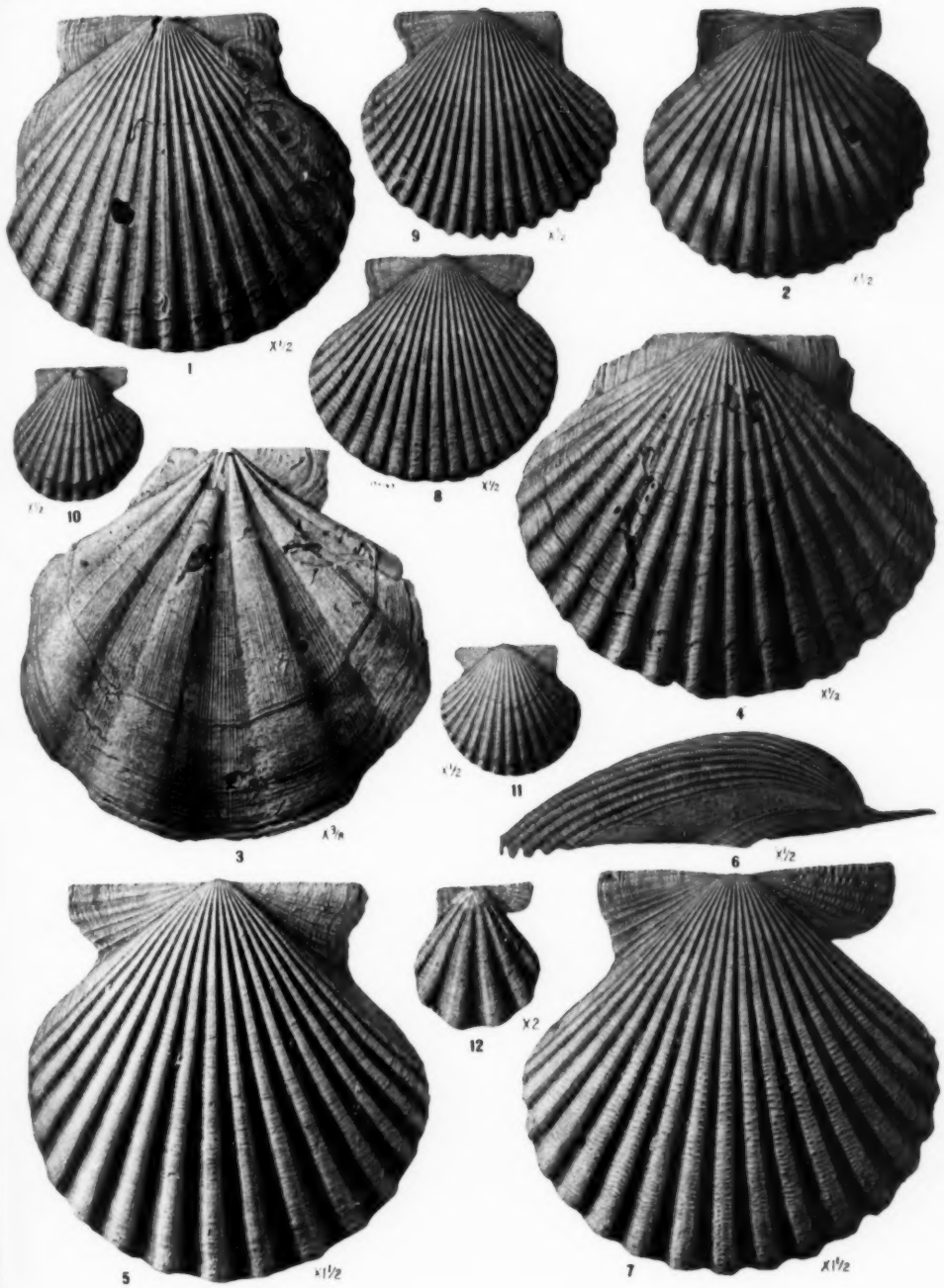
4—Pecten (*Chlamys*) *gladensis* Mansfield, n. sp., holotype, left valve, ×½, U.S. Nat. Mus. 373077. (p. 188)

5–7—Pecten (*Chlamys*) *gibbus anteamplicostatus* Mansfield, n. subsp., syntypes, ×½, U.S. Nat. Mus. 373078; *5*, left valve; *7*, right valve; *6*, view of nearly smooth submargin on anterior side of left valve. (p. 189)

8, 9—Pecten (*Chlamys*) *evergladensis charlottensis* Mansfield, n. subsp., syntypes, ×½, U.S. Nat. Mus. 154183; *8*, right valve; *9*, left valve. (p. 189)

10, 11—Pecten (*Chlamys*) *charltonius* Mansfield, n. sp., syntypes, ×½, U. S. Nat. Mus. 373080; *10*, right valve; *11*, left valve. (p. 190)

12—Pecten (*Chlamys*) *skiptonensis* Mansfield, n. sp., holotype, right valve, ×2, U. S. Nat. Mus. 143658. (p. 186)



Mansfield, Tertiary Pectens

rather closely spaced concentric lamellae. Middle of disk the highest part of the valve; away from the middle the surface gradually declines to the margins. Ribs 17 in number, rounded in outline, separated by spaces about as wide as the ribs; ribs, interspaces, and submargins without any visible subradials. The concentric lamellae over the whole shell are rather widely spaced.

Dimensions of holotype: Left valve (U. S. Nat. Mus. 373077), length, 120 mm.; height, 101 mm.; convexity, about 23 mm.

The new species appears to be closely related to specimens dredged from Tampa Bay, just off shore opposite Vinoy Hotel at St. Petersburg, Florida, and identified by me as "*Pecten eboreus*" Say (8*c*); but it differs from the latter form in having a much larger, relatively longer and more equilateral shell.

The general outline of the new species agrees closely with a left valve from the Pleistocene on North Creek at Asprey, Florida, referred by Dall (9*j*) to *Pecten gibbus irradians* Lamarck, but differs in having a larger shell with a lower umbonal area. No right valve of the new species is at hand for comparison.

Type locality: Station 12923, thrown out of a ditch in the Everglade area about 18 miles south of Immokalee, Collier County, Florida. Collected by Clarence Simpson of the Florida Geological Survey.

Horizon: Same horizon as the limestone of southern Florida, the fauna from which was described by Mansfield (22) and referred to the Pliocene.

The two specimens, probably left valves, from the type locality, although having squarer ribs, probably belong to the same new subspecies.

PECTEN (CHLAMYS) GIBBUS ANTEAMPLICOSTATUS Mansfield, n. subsp.

Plate 23, figures 5–7

Pecten gibbus amplicostatus DALL (part), *1898*, Wagner Free Inst. Sci., Trans., vol. 3, pt. 4, p. 747.

The holotype of *P. gibbus amplicostatus* Dall, a Recent specimen from Texas (U. S. Nat. Mus. 106990), is figured in the Proceedings of the United States National Museum, vol. 24, pl. 32, fig. 9, 1902. Dall's type specimen, as well as other Recent specimens referred to his subspecies, have radially striated submargins. The specimens from the Pliocene Caloosahatchee marl that Dall included under his subspecies have smooth submargins and are here treated as a new subspecies. The Pliocene form also has wider submargins and 3 to 4 more ribs. In other features it is similar to the Recent form.

Dimensions of syntypes (U. S. Nat. Mus. 373078): Right valve, length, 39 mm.; height, 37 mm.; convexity, 19 mm. Left valve, length, 39 mm.; height, 37 mm.; convexity, 19 mm.

Type locality: Caloosahatchee River (exact place on the river not known), Florida.

Horizon: Pliocene Caloosahatchee marl.

Known occurrences: Station 1/1170, one mile below highway bridge at Labelle, Hendry County, C. W. Cooke, Stuart Mossom, and W. C. Mansfield collectors; Station 3300, Shell Creek, Charlotte County; both in Florida.

PECTEN (CHLAMYS) EVERGLADENSIS CHARLOTTENSIS Mansfield, n. subsp.

Plate 23, figures 8, 9

Shell of medium size; left valve more strongly convex than right, both valves inequilateral, the posterior region being more produced. Anterior ears slightly larger than posterior; right anterior ear weakly sinuate, sculptured with 5 radials crossed by closely spaced lamellae; right posterior ear sculptured with 8 radials crossed by closely spaced lamellae. Submargins steep, sculptured only with fine, crowded lamellae. Ribs 21 in number, rather high, nearly flat topped, weakly undercut on the sides. Interspaces on the right valve slightly narrower than

the ribs; on the left valve about equal in width.

Dimensions of syntypes (U. S. Nat. Mus. 154183): Right valve, length, 70 mm.; height, 63 mm.; convexity, 16.5 mm. Left valve, length, 72.5 mm.; height, 64 mm.; convexity, 19.5 mm.

The new subspecies differs from *Pecten evergladensis* Mansfield in having squarer ribs, more closely spaced concentric lamellae and a relatively narrower shell; and from *Pecten gibbus irradians* Lamarck, a Recent species of Florida, in having a more inequilateral shell, smooth instead of radially striate submargins, a lower right valve and a slightly higher left valve. *P.* (*C.*) *circularis* Sowerby, a Recent species that ranges along the Pacific coast from Monterey, California, to Paita, Peru, is very closely related to the new subspecies, differing mainly in having wider and less squarely cut ribs.

Type locality: Shell Creek, Charlotte County, Florida, Joseph Wilcox, collector.

Occurrence: Pliocene Caloosahatchee marl: Shell Creek (common); Caloosahatchee River (rare); Alligator Creek (?), small specimen.

PECTEN (CHLAMYS) CHARLTONIUS
Mansfield, n. sp.

Plate 23, figures 10, 11

Shell rather small, solid; valves inflated, the left slightly more so than the right, inequilateral, the posterior region being more produced. Right anterior ear with a moderately deep notch, sculptured with about 4 rather strong radials. Right posterior ear sculptured with 3 or 4 weak radials on figured cotype but on some other cotypes with 7 or 8 radials. Ribs low, rather wide, nearly smooth, flat, 17 on each valve; interspaces shallow, round bottomed, a little narrower than ribs. Submargins without radials. Concentric lamellae more strongly developed between the ribs than on them.

Dimensions of syntypes (U. S. Nat. Mus. 373080): Right valve, length, 40 mm.; height, 37 mm.; convexity, 11 mm. Left valve, length, 40 mm.; height, 37 mm.; convexity, 12 mm.

Pecten charltonius appears to be closely related to *Pecten evergladensis charlottensis* Mansfield, from the Pliocene Caloosahatchee marl, but differs from the latter in having a smaller shell, and fewer, wider, and less squarely cut ribs.

Type locality: Station 6427, south abutment of Atlantic Coast Line R.R. bridge, St. Marys River, Nassau County, Florida; G. C. Matson, collector.

Occurrence: Charlton formation, probably of Pliocene age.

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THE FUSULINID GENUS *VERBEEKINA*

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ABSTRACT

Eight species, one new, are referred to *Verbeekina;* at least five other forms may represent distinct species. The genus is diagnosed, its occurrence is discussed, and it is compared with other closely related genera. The genotype, *V. verbeeki* (Geinitz), is described and illustrated

The genus *Verbeekina* Staff was proposed in 1909 as a subgenus of *Doliolina* Schellwien. It has since been placed in synonymy with several other genera, and it has also been made the type of the subfamily Verbeekininae. Its status is therefore of more than ordinary importance in the classification of the fusulinids. Furthermore, paleontologists have expressed quite different opinions in regard to the precise nature of some of the structures of representatives of this genus, particularly of the genotype, *V. verbeeki* (Geinitz). I have well-preserved material from the Padang Highlands of western Sumatra that shows clearly the internal structures of the type species, and I have made a thorough study of this material and have compared it with all other congeneric forms.

NOMENCLATURAL HISTORY OF VERBEEKINA

When Staff (1) designated *Fusulina verbeeki* Geinitz as the subgenotype of *Verbeekina*, he considered that it differed from the subgenotype of *Doliolina* Schellwien, *D. lepida* (Schwager), primarily in that it did not possess parachomata, which are present throughout all volutions of the latter. He recognized, however, that the spirotheca of both subgenotypes possesses essentially the same structure.

In 1925 Ozawa (2) discussed *Verbeekina*, concluding that it does possess parachomata, but that they are very poorly developed in the inner volutions and are well developed and continuous across the chambers only in the outermost volutions. He apparently based his conclusions on specimens from Japan that he identified as *V. verbeeki*, and to support these conclusions he illustrated, by a drawing, the development of the parachomata in a broken portion of one of these specimens. Nevertheless, Ozawa still considered the types of *Verbeekina* and *Doliolina* to be at least subgenerically distinct, for he believed that the type of *Doliolina* has a spirotheca composed of only a tectum, whereas in *Verbeekina* it is composed of a tectum and a "keriotheca." However, Ozawa was basing his concept of *Doliolina lepida* (Schwager) on a form from Japan that Yabe and Hanzawa (3) believe not even congeneric with *D. lepida* and that they have named *Pseudo-*

doliolina ozawai (4). Shortly before his untimely death in 1929, Ozawa examined Schwager's types of *D. lepida* in Berlin, concluding (5) that it has a spirotheca containing keriotheca, as illustrated by Schwager in his original drawing, and that there does not seem to be any basis for separation of *Doliolina* and *Verbeekina* (6).

Verbeekina assumed greater importance in the classification of the fusulinids when Staff and Wedekind (7) raised it to the rank of a genus and made it the type of the subfamily Verbeekininae. In 1930 Dunbar and Henbest (8), on the information supplied them by Ozawa, suppressed *Verbeekina* as a synonym of *Doliolina*, Doliolininae accordingly replacing the subfamily name Verbeekininae. Although this change has not been followed by Yabe and Hanzawa (9), Galloway (10), or Lee (11), or by Dunbar (12) himself, Tan (13) studied *Fusulina verbeeki* Geinitz from Guguk Bulat, Sumatra, and concluded that *Doliolina* should include the type of *Verbeekina*. Tan believes that the development of the parachomata is a variable character within even the same species or variety, and that the nature of the parachomata is not hereditary, views which are not borne out by my observations. In the genotype, *V. verbeeki*, axial sections may cut the parachomata in such a fashion as to show an apparent difference in the degree of development for corresponding portions of different specimens, but this is due to the position of the section and not to a true difference in the development of the parachomata. It is true that any one of the parachomata may differ slightly in development from one chamber to the next, but in all well preserved specimens the parachomata are probably very similar in degree of development for corresponding volutions.

SCOPE OF THE GENUS

Five species and two varieties (all of which I am regarding as distinct species) have been described that are definitely referable to *Verbeekina*. These are *Fusulina verbeeki* Geinitz, 1876 (the genotype); *V. verbeeki volzi* Staff, 1909; *Schwagerina douvillei* Deprat, 1912; *Schwagerina* (*Verbeekina*) *pseudo-verbeeki* Deprat, 1913; *Schwagerina* (*Verbeekina*) *deprati* Yabe (14), 1925; *Verbeekina verbeeki sphaera* Ozawa (15), 1925; Verbeekina minor Chen, 1934. A complete synonymy of these seven species would include over forty references; in over twenty, illustrations have been included. In at least thirty-eight publications the species *V. verbeeki* has been discussed, but certainly not all of the specimens considered are conspecific with Geinitz's types from Sumatra.

In addition to the locality in Sumatra that yielded the specimens on which *Verbeekina* was based, the genus is known from Java, French Indo-China, Japan, China, Afghanistan, Russian Turkestan, Turkey, Greece, and Sicily.

In 1909 Staff (16) illustrated an axial section as "*Verbeekina verbeeki* Gein. Typus. Originalschliff Ver-

beeks. 'Padang 1876"' (17). Staff merely stated that Roemer had obtained this material from Verbeek in 1876. In 1883 Schwager (18) described and illustrated by drawings *V. verbeeki*, stating that he had obtained topotype material from Verbeek, Roemer, and Geinitz, but he also stated that this species occurred in Japan and China. Schwager apparently based his illustrations either on topotypes or on a part of Geinitz's syntypes (19).

In 1914 Deprat (20) described a form from Akasaka, Japan, as *Schwagerina* (*Verbeekina*) *verbeeki* that is definitely not conspecific with the types. This Japanese form is smaller than *verbeeki*, has a more elongate axis of coiling, and apparently has a more rapidly thickening spirotheca. In 1925 Ozawa (21) referred Deprat's form to *V. verbeeki sphaera* Ozawa. In so far as I can tell from the published illustrations and descriptions, *V. sphaera* is much smaller than Deprat's form and has a different shape. Since Deprat's form from Akasaka differs so markedly from all other recognized representatives of this genus, I am proposing for it the name *Verbeekina akasakensis* Thompson, n. sp. The specimens from Yunnan, China, which Deprat described as *Schwagerina verbeeki* in 1912, and which Yabe has named *Verbeekina deprati*, are close to *V. akasakensis*, for, as has been pointed out by Deprat, their shells expand at approximately the same rate and they are about the same size. However, their inner volutions are quite different in shape, the shell of *V. akasakensis* is more elongate, and the septa are more numerous.

Verbeekina douvillei (Deprat) was based on specimens from Yunnan (China) and French Indo-China. In 1914 Deprat (22) described as *Schwagerina* (*Verbeekina*) *douvillei* a form from Akasaka, Japan, which is much larger and has more volutions than the type specimens, but its shell has a very similar shape and expands at about the same rate. The development and number of septa in the inner volutions of these two forms are different and the spirotheca of the Japanese form is considerably thinner. It therefore seems to me that Deprat has misidentified the Japanese form and that it probably is a distinct species. These two forms have been placed in synonymy with *V. verbeeki* by Colani and Ozawa. However, the rapid rate of expansion, the very large size, and the much poorer development of the parachomata of *V. douvillei* definitely distinguish it from *V. verbeeki*.

In 1924 Colani (23) critically reviewed Deprat's four memoirs on fusulinids, reaching the conclusion that *V. verbeeki* and *V. douvillei* are synonymous and *V. pseudo-verbeeki* merely a variety of *V. verbeeki*. However, the specimens from Cambodge, French Indo-China, that Colani (24) figured as *V. verbeeki* are probably not conspecific with the types of this species and are apparently not referable to any previously described species. Since I am not able to tell definitely on which specimens Colani based her description, I hesitate to propose a new name for this form. It

resembles somewhat *V. pseudo-verbeeki*, but the development of its shell is different, it apparently does not have as highly developed parachomata, and, as Colani has pointed out, there is a larger number of septa for corresponding volutions than in *V. pseudo-verbeeki*. It seems to me that *V. pseudo-verbeeki* should be regarded as a distinct species, for it is larger than *V. verbeeki*, has more numerous volutions and a larger number of foramina for corresponding volutions—in *V. pseudo-verbeeki* there are 104 foramina in the twelfth volution; in *V. verbeeki* about 50.

The form from Afghanistan which Hayden (25) illustrated as *Schwagerina princeps* (Ehrenberg), and which he considered conspecific with *Verbeekina verbeeki*, is clearly referable to the genus *Verbeekina*, but Hayden's specimens have never been thoroughly described and his illustrations may possibly be of immature or incomplete specimens; hence, I am deferring detailed specific comparisons. This form may represent a species distinct from any of those mentioned above.

Silvestri (26) described a representative of this genus from the Sosio beds of Sicily as *Verbeekina verbeeki* (Geinitz). Some of the specimens illustrated by Silvestri seem to be identical with typical *V. verbeeki* from Sumatra. However, the slightly uncentered sagittal section, his Pl. 3, fig. 4, is certainly not conspecific with his other illustrated specimens, and it more probably represents *Schwagerina yabei* Staff. Ozawa and Tobler (27) briefly described as *Verbeekina verbeeki* part of a sagittal section from Pesulia, Island of Katakupho (between Naxos and Amorgos), Greece. However, this specimen is not satisfactory for certain determination.

From a study of specimens of the genotype from western Sumatra and from the many published descriptions and illustrations of this species and other congeneric forms, I have drawn up the following generic diagnosis of *Verbeekina*.

Genus VERBEEKINA Staff

Shell large, spherical to subspherical. External furrows shallow but distinct. Mature forms typically consist of 12 to 21 volutions, are 3.5 to 14 mm. in length, and have a form ratio of 1 : 1.0 to 1 : 1.2. Spirotheca thin; of two primary layers, tectum and "keriotheca." Upper and lower surfaces of spirotheca, except in outer volution, covered with very thin layers of dense calcite, the structure of which resembles very closely that of the parachomata. In extreme polar regions of outer three or four volutions of mature forms, chambers essentially filled with these deposits. "Alveoli" of keriotheca very distinct but extremely fine; apparently not branching in their upper portions as in *Triticites*, *Schwagernia*, and *Parafusulina*. Septa composed of downward deflection of tectum and keriotheca of spirotheca. Keriotheca much thinner, denser near bottoms of septa. On anterior side of tectum, keriotheca of the spirotheca extends with rapidly decreasing thickness about one-fourth the distance down the septa. Septa coated on both sides with dense calcite which resembles in structure the parachomata. Septa unfluted throughout length of shell, extending forward to join spirotheca of preceding volution at an angle of about 70°. Basal portion of septa penetrated by low elliptical foramina which may number over 100 in the

twelfth volution. Parachomata developed in space between foramina extending anteriorly from the septa, usually with rapidly decreasing height. In inner 10 volutions parachomata rudimentary, not extending completely across the chambers in any described species; usually only a faint suggestion of parachomata in the inner volutions. In outermost volutions parachomata may extend completely across the chambers and join the slightly developed posterior portion of parachomata of following chamber so as to form a more or less continuous ridge. However, even in outermost volutions of most forms parachomata not continuous throughout; but they may reach completely across one chamber and not across following chamber. Parachomata less than one-fourth the height of the chambers at their maximum development. Proloculum very minute, spherical; normally with inside diameter of 20 to 60 microns. Juvenarium endothyroid, very tightly coiled, normally with a form ratio of less than 1.4 : 1. Volutions become highly inflated at end of juvenarium; of essentially uniform height throughout remainder of shell. Shell assumes mature shape at end of fifth or sixth volution.

The genus *Verbeekina* is perhaps more closely related to the genus *Eoverbeekina* Lee than to any other genus of fusulinids. However, these two genera can be easily distinguished, for the latter has a tunnel whereas *Verbeekina* does not; it has foramina only in the outer volutions, and not as well developed parachomata as in *Verbeekina*. *Verbeekina* can be distinguished from *Doliolina* by the differences in the shapes of the shells, in the development of the juvenaria, and in the development of the parachomata. In the genotype of *Doliolina*, the shell is elongate-ellipsoidal, and the parachomata are well developed throughout.

The specimens from the Permian of Cammon, French Indo-China, described by Deprat (28) in 1915 as *Doliolina compressa* have a form-ratio of about 1.5 : 1, are markedly umbilicate, have a juvenarium which is truly endothyroid, and have very high, well-developed parachomata throughout the shell. Although this form has parachomata somewhat similar to those of the genotype of *Doliolina* and the spirotheca is similar, the general shapes of the shells of the two forms are quite different and they should probably not be placed in the same genus—eventually a new generic name will have to be proposed for *D. compressa*.

The position of *Verbeekina* in the phylogenetic series of the fusulinids is problematical. I am inclined to doubt that it is a descendent of *Fusulinella* or of *Fusulina*, but it seems probable that these forms are the descendents of *Staffella* or that they and *Staffella* arose from a common ancestor. In diagnosing *Eoverbeekina* in 1933, Lee (29) pointed out that *Verbeekina* was derived from forms which possessed a tunnel and that it is rather closely connected with the other members of the Fusulinidae. Nevertheless, it seems doubtful to me that we should include *Verbeekina* and *Fusulina* in the same family.

The stratigraphic range of *Verbeekina* is not well known. Most of its representatives are from Asiatic strata, the exact geologic ages of which are still somewhat uncertain. However, it seems safe to conclude that the genus is confined to the Permian, and apparently it did not make its appearance until Middle Permian time.

VERBEEKINA VERBEEKI (Geinitz)

Plate 24, figures 1–8

Fusulina princeps BRADY, *1875*, Geol. Mag., n. s., dec. 2, vol. 2, pp. 537–538, pl. 13, figs. 6a–6c.

Fusulina verbeeki GEINITZ, *1876*, Palaeontographica, Bd. 22, pp. 399–400.—STACHE, *1876*, K.-K. Geol. Reichsanst., Verh., Jahrg. 1876, pp. 370–371.

Schwagerina verbeeki MÖLLER, *1879*, Acad. Imp. Sci. St. Pétersb., Mém., sér. 7, t. 27, no. 5, p. 9.—ROEMER, *1880*, Lethaea Geognostica I, pp. 277–278, figs. 46a–46c.—ROEMER, *1880*, Palaeontographica Bd. 27, p. 4,pl. 1, figs. la, lb.—SCHWAGER. *1883*, Richthofen's China, Bd. 4, pp, 135–137, pl. 16, figs. 14, 17, 18, pl. 17,

figs. 9–17.—VERBEEK and FENNEMA, *1896*, Description géologique de Java et Medoura, vol. 2, sect. 5, p. 1134, pl. 1, figs. 11–22.—(?)LÖRENTHEY, *1899*, Széchenyi's Ostasien, Bd. 3, Abt. 4, p. 266.—YABE, *1902*, Geol. Soc. Tokyo, Jour., vol. 9, pp. 1–2, textfig. 1.—(?) YABE, *1906*, Imp. Univ. Tokyo. Jour. Coll. Sci., vol. 21, art. 5, p. 27, pl. 1, fig. 2.—(?) DE GREGORIO, *1930*, Ann. Géol. Paléont., Livr. 52, p. 50, pl. 20, figs. 20–29.

Möllerina verbeeki SCHELLWIEN, *1898*, Palaeontographica, Bd.44, p. 258.

Doliolina verbeeki? SCHELLWIEN, *1901*, Phys.-Ökon. Gesell. Königsberg, Schrift., Jahrg. 42, p. 68.—YABE, *1903*, Geol. Soc. Tokyo, Jour., vol. 10, p. 6.—VOLZ, *1904*, Geol. Paläont. Abh., N. F., Bd. 6, Heft 2, p. 98.—DOUVILLÉ, *1906*, Soc. Géol. France, Bull., sér. 4, t. 6, p. 582.—SCHELLWIEN, *1911*, Futterer's Durch Asien, p. 129.—TAN, *1933*, Dienst Mijnb. Nederl.-Indië, Wetensch. Med., no. 25, pp. 57–65, pl. 1, figs. 1–6.—SCHUCHERT, 1935, Geol. Soc. Am., Bull., vol. 46, pp. 17, 30.

Schwagerina princeps? HAYDEN, *1909*, Geol. Survey India, Records, vol. 38, pp. 242–243, pl. 18, figs. 1–6.

Verbeekina verbeeki STAFF, *1909*, Neues Jahrb. Min., Geol. Paläont., Beil.-B. 27, textfig. 6, pl. 7, figs. 5, 7.—STAFF, *1910*, Zoologica, Heft 58, textfigs. 26–28, 39, pl. 1, fig. 6.—STAFF, *1912*, Palaeontographica, Bd. 59, pp. 190–191.—SCHUBERT, *1915*, Nederl. Timor-Expeditie, Jaarb. Mijnwezen, 43e Jaarg., pp. 176–177.—SCHUBERT, *1915*, Paläont. Timor, Lief. 2, p. 52.—(?)OZAWA, *1925*, Geol. Soc. Tokyo, Jour., vol. 32, p. 22.—OZAWA, *1925*, Imp. Univ. Tokyo, Jour. Coll. Sci., vol. 45, art. 4, pp. 13–17, pl. 1, fig. 3.—OZAWA, *1925*, Imp. Univ. Tokyo, Jour. Coll. Sci., vol. 45, art. 6, pp. 48–51, pl. 10, figs. 6, 7.—LANGE, *1925*, Geol. Mijnb. Genootschap Nederl. Koloniën, Verh., geol. ser., deel 7, pp. 260, 261, pl. 3, fig. 66a; pl. 5, 66b.—(?) OZAWA and TOBLER, *1929*, Eclogae geol. Helvetiae, vol. 22, p. 48, pl. 5, fig. 5.—YABE and HANZAWA, *1931*, Leidsche Geol. Med., deel 5, p. 26.—CHAPUT, *1932*, Acad. Sci. Paris, C. R., vol. 194, p. 1593.—SILVESTRI, *1933*, Ist. Geol. R. Univ. Padova, Mem., vol. 10, pp. 34–35, pl. 1, figs. 10–12; pl. 3, figs. 3, 5.—GALLOWAY, *1933*, A manual of foraminifera, p. 407.—DUNBAR, *1933*, Cushman's Lab. Foram. Research, Special Pub. no. 4, p. 138.—FROMAGET, *1934*, Soc. Géol. France, Bull., sér. 5, t. 4, p. 387.—GUBLER, *1934*, Soc. Géol. France, Bull., sér. 5, t. 4, pp. 443–447.—CHEN, *1934*, Palaeontologia Sinica, ser. B, vol. 4, fase. 2, pp. 101–102, pl. 16, fig. 1.

Schwagerina (*Verbeekina*) *verbeeki*? DEPRAT, *1913*, Service Géol. Indochine, Mém., vol. 2, fasc, 1, p. 47.—(?) YABE and HAYASAKA, *1920*, Geog. Research in China, vol. 3, p. 10, pl. 17, fig. 4.

Shell large, spherical. External furrows shallow but well defined. Axis of coiling essentially straight throughout length of shell. Specimens of 15 volutions about 7.0 mm. long, 7.0 mm. wide; specimens of 16 to 18 volutions 8.0 to 11.0 mm. long, 8. 0 to 11.0 mm. wide. Mature forms consist of 15 to 18 volutions. Form-ratio 1.5 : 1 for second volution, 1.3 : 1 for third volution, 1 : 1.0 for remaining outer volutions. Specimens of 1 to 15 volutions, respectively, 0.082, 0.168, 0.254, 0.444, 0.686, 1.154, 1.744, 2.454, 3.164, 3.890, 4.548, 5.206, 5.864, 6.470, and 7.094 mm. wide.

Proloculum very small, spherical. Inside diameter about 30 microns. Juvenarium very tightly coiled, but chambers of outer 10 volutions rather uniform in height. Heights of chambers of first 15 volutions, respectively, 26, 43, 43, 95,

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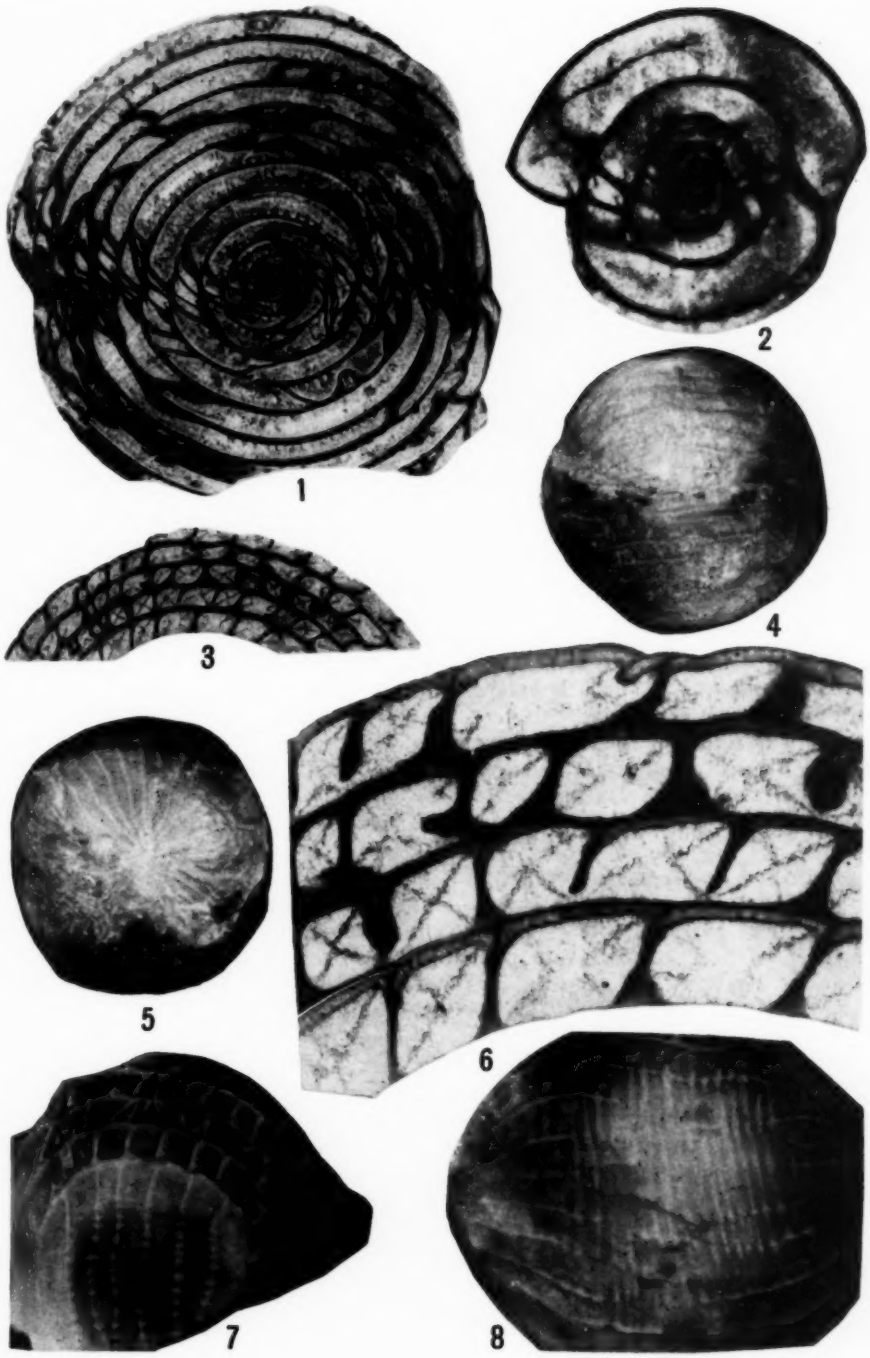
EXPLANATION OF PLATE 24

All illustrations on this plate are unretouched photographs representing *Verbeekina verbeeki* (Geinitz) from the Padang Highland, Boekit Besi, Sumatra.

FIGS. *1–8*—*Verbeekina verbeeki* (Geinitz). *1*, Axial section which passes through the proloculum on only one side, ×10; *2*, enlarged portion of the same section as fig. 1, ×40; *3*, a portion of a sagittal section, ×10; *4*, *5*, external views, ×5.6; *6*, enlarged portion of the same section as fig. 3, ×40; *7*, the lower surface of the tenth volution of a specimen of fifteen volutions which shows the rudimentary development of the parachomata; ×10; *8*, a portion of the etched surface of a specimen of fifteen volutions which shows the partially continuous parachomata, ×10. (p. 197)



Thompson, Permian Foraminifer

UNIV. OF MICH.

121, 234, 295, 355, 355, 363, 329, 329, 329, 303, and 312 microns.

Spirotheca relatively thin; thickness varies considerably from one volution to next; it may decrease in thickness as much as 10 microns from one volution to following volution. Spirotheca increases in thickness from about 10 microns in fifth volution to about 40 microns in tenth volution and to 45 to 50 microns in fourteenth and fifteenth volutions. Keriotheca has a fibrous-like ("alveoli") structure; "alveoli" in thirteenth volution about 3 microns in diameter; these fibres or alveoli very uniform in size from top to the bottom of keriotheca; apparently not similar in structure to alveoli of other genera of fusulinids, such as *Triticites* and *Schwagerina*, which decrease in coarseness and branch toward the tectum. Upper and lower surfaces of spirotheca, as well as both sides of septa, coated by a thin layer of dense calcite similar in density to calcite of parachomata; probably deposited at time of formation of parachomata. In outer 3 or 4 volutions, where septa are very close together in extreme polar regions, these deposits almost completely fill the chambers.

Septa rather thin, extending forward to meet spirotheca of preceeding volution at an angle of about 70°; rather numerous, about 36 septa in fifteenth volution. Septa unfluted throughout length of shell.

Foramina elliptical to circular in cross-section, very numerous. About 7 foramina in fourth volution, 19 in eighth volution, 48 in twelfth volution, and 60 in sixteenth volution. Parachomata well developed only in outer 5 to 8 volutions of mature specimens; in inner 8 volutions parachomata undeveloped to rudimentary; in tenth volution parachomata rudimentary, extending less than one-third the distance across the chambers (Pl. 24, fig. 7); In fifteenth volution parachomata about one-fourth as high as chambers immediately adjacent to septa, but reduced to very low narrow ridges as they extend across the chambers (Pl. 24, fig. 8). Even in outermost volution of mature forms, parachomata not continuous across all chambers; they may be continuous across one chamber but not extend completely across following chamber.

Remarks.—*Verbeekina volzi* was figured by Staff (30) as a variety of *V. verbeeki*. The types came from "Buk Bessi," Sumatra. The illustration is stated by Staff to be ×20 and it seems probable that this magnification is correct, though, as explained, the magnification given for another figure (fig. 5 = *V. verbeeki*) on the plate is probably in error (18). If the stated magnification of this illustration is correct then *V. volzi* is much smaller than *V. verbeeki* and its spirotheca is relatively much thicker. If the magnification of this type of *V. volzi* is ×10, then the very thick spirotheca definitely distinguishes these two species. Thus, in either case, the two forms must be regarded as representing distinct species. *V. douvillei* (Deprat) has a much more expanded shell beyond the juvenarium, it is larger for corresponding volutions, and apparently it has less well developed parachomata than *V. verbeeki*. The form from Akasaka, Japan, described by Deprat in 1914 as *V. douvillei*, and which is probably a distinct species, has more highly expanded chambers beyond the juvenarium, is much larger in size, has thinner spirotheca, has less well developed parachomata, and contains more volutions than *V. verbeeki*. *V. pseudoverbeeki* Deprat is much larger, has more numerous volutions, and has a larger number of foramina than *V. verbeeki*. *V. akasakensis* (p. 195) is smaller, has a more slowly expanding shell, and is more elongate than *V. verbeeki*. Also, the septa are more numerous in the inner ten volutions of *V. akasakensis*.

Occurrence.—The syntypes of this species were collected by Verbeek from the Padang Highlands of western Sumatra and they were given to Geinitz for description. In his description of the geology of this part of Sumatra, Verbeek (31) gave a section extending from

the city of Padang to the northeast to show the position of the fusulinid-bearing limestone, but neither he nor Geinitz stated definitely the locality in the Padang Highlands from which the syntypes of *V. verbeeki* came. Later, however, Verbeek and Fennema (32) stated that this form was known only from Boekit Besi near Singkarah Lake and in the vicinity of Sibrambang. My material was collected by G. Boehm from Boekit Besi, Sumatra. Specimens which may be conspecific with these syntypes have been reported by a number of paleontologists from French Indo-China, China, Japan, Java, Turkey, Russian Turkestan, Greece, and Sicily. Also, the forms illustrated by Hayden from Afghanistan may represent this species. Illustrations were not given by Schellwein of his specimens from Russian Turkestan, and Chaput did not give illustrations of his specimens from Turkey; it is therefore uncertain if the specimens found in these localities are in reality conspecific with the types from Sumatra.

Addendum.—Since this study was completed, Dr. Hubert G. Schenck has kindly sent me specimens of *Verbeekina verbeeki* (Stanford Univ., 5947), which Dr. Tan Sin Hok sent him from Musper's collection made at Guguk Bulat, Sumatra. A careful study of these specimens indicates to me that they are conspecific with my material from Boekit Besi and that the development of their parachomata is like that of the specimens illustrated on plate 24. However, these specimens are highly silicified, as apparently were those illustrated by Tan, and the parachomata were partially destroyed during fossilization in some portions of the specimens. Tan's conclusion that the development of the parachomata is variable even for the same species is probably due to the poor state of preservation of his specimens.

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4. The status of this genus does not enter into our problem, but Lee (*Nat. Research Inst. Geol., Mem.*, no. 14, p. 7, 1933) has discussed the genotype and has expressed some doubt as to its generic distinction from the type of *Doliolina*. Through the kindness of Professor Yabe I have examined type material of this genus from Akasaka and it seems to me that its spirothecal structure is like that of *D. lepida*. However, on the basis of other differences I am tentatively recognizing both *Doliolina* and *Pseudodoliolina*.
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6. It is of interest to note in this connection that Ozawa did not consider the parachomata important in the separation of *Doliolina* and *Verbeekina*, for he has included in *Verbeekina* several forms with well-developed parachomata throughout all volutions of the shell, such as *Doliolina claudiae* Deprat, which are clearly congeneric with the type of *Doliolina*.
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14. This specific name was first published by Hayasaka (*Tohoku Imp. Univ., Sci. Rept.*, vol. 8, p. 15, pl. 2, fig. 8; pl. 3, fig. 1, 1925) as "*Schwagerina* (*Verbeekina*) *deprati* Yabe (MS)," but, in so far as I have been able to determine, Yabe has never illustrated or described the types from China. Hayasaka figured an uncentered axial section from Japan and referred it with some hesitation to this

species. However, Hayasaka stated that this name was proposed by Yabe for Deprat's *V. verbeeki* of 1912 (*Service géol. Indochine, Mém.*, vol. 1, fasc. 3, pp. 40–41, pl. 1, figs. 7–11) and hence I am regarding Deprat's specimens as the types of *V. deprati* Yabe.

15. In 1930 De Gregorio (*Ann. Géol. Paléont. Livr.* 52, p. 50, pl. 20, figs. 30–31) described from the Sosio beds of Sicily "*Schwagerina verbecki orbulinopsis*" [given in the legends of the plates as "*S. verbeki orbicularis*"], but unfortunately De Gregorio's illustrations are not satisfactory and his description is too brief and generalized. The distinguishing characters cannot be determined until his types are restudied.
16. Op. cit. in reference 1, pl. 7, fig. 5.
17. STAFF gave the magnification of his illustration of this axial section of about twelve volutions as "×20," which would give a length of about 3 mm. for this specimen. However, several reasons lead me to believe that Staff's illustration is only about ×10. In the first place, the illustration shows too thin a spirotheca, and further, all described and illustrated topotype material of this species, including my own material of twelve volutions and the topotypes (probably from the same collection as Staff's specimen) described and illustrated by Brady in 1876 and by Roemer in 1880, show that specimens of twelve volutions are about 6 mm. in length. If Staff's published magnification is correct, his specimen is not conspecific with other forms referred to *V. verbeeki*.
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19. Staff (*Zoologica*, Heft 58, Bd. 22, no, 6, p. 40, 1910), who had access to Schwager's collections, has reproduced these illustrations and stated that the specimens which they represent came from Sumatra.
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TWO NEW INSECTIVORES FROM THE LOWER PALEOCENE OF NEW MEXICO

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ABSTRACT

Puercolestes simpsoni, assigned to the Deltatheridiidae, is intermediate between *Deltatheridium*, Cretaceous, and *Didelphodus*, Eocene. *Escatepos* is assigned with doubt to the Oxyclaeninae, primitive creodonts.

The Puerco, or lowermost formation of the Paleocene, has but a limited exposure in the San Juan Basin, New Mexico. An equivalent is probably present in the lowermost Fort Union of the Big Horn Basin, Wyoming. None is known elsewhere. During the last field expedition for St. Louis University, I explored the various sites in the San Juan Basin worked by Sinclair and Granger in 1914.

The Kimbetoh locality yielded a fair collection of isolated teeth and jaw fragments of placental mammals, nearly all of them being periptychids. In the bad lands about 5 miles south of Kimbetoh Arroyo a more abundant collection was made in a shallow basin hollowed out of the sediments overlying the Ojo Alamo, or Upper Cretaceous. In this locality I had the good fortune to find two little skulls of insectivores in a remarkable state of preservation, considering the fragmentary nature of fossils usually encountered in these beds.

The new specimens, *Puercolestes simpsoni* and *Escatepos campi*, represent new genera and are affiliated with a group whose history is shrouded in much uncertainty by reason of the scant and fragmentary record left behind by the mammals of Puerco and pre-Puerco times. This fact has caused some confusion among the students of these difficult forms. Even today, after many years of discussion and painstaking labor, the paleontologist follows with difficulty the trail left by the primitive pantotheres or the later Mesozoic mammals into the Puerco sediments.

Zalambdodonts and leptictids.—The precise relationships of the zalambdodonts and the leptictid insectivores are perhaps little nearer solution today than they were at the time the first specimens were unearthed in the valley of the San Juan in the days of Cope. Simpson remarks in his concise account of the most recent finds from Mongolia that the morphology of the teeth of the several groups is quite confusing and he had available for study all the known specimens with the exception of the specimens described in this paper. In a word, it is extremely difficult to define these groups, for the reason that the fossil forms do not lend themselves to

classification within ordinal limitations.

The question of greatest importance, whether or not the zalambdodonts gave rise to the more normal type of tritubercular dentition of Eocene times, or whether they are rather a specialization of primitive tritubercular forms and in no way ancestral, does not find a certain and satisfying answer. However, it must be admitted that the increasing number of specimens from Paleocene localities and the remarkable finds from the Cretaceous of Mongolia have gone a long way to shed light on a very murky problem.

The Mongolian insectivores.—Gregory and Simpson (1926) assign the Mongolian forms as follows:

Deltatheridiidae:
Deltatheridium pretrituberculare
Deltatheroides cretacicus
Hyotheridium dobsoni
Zalambdalestidae:
Zalambdalestes lechei
Zalambdalestes grangeri

To sum up Gregory's and Simpson's conclusions it may be said that they considered the Zalambdalestidae as ancestral to the zalambdodonts, admitting, however, that the paracone and metacone are more separate and more buccal than one would find in any undoubted zalambdodont. This is an instance of the difficulty of fitting these specimens into a hard and fast category. They further acknowledge the many resemblances of the Zalambdalestidae to the Leptictidae and suggest that in Cretaceous times the two groups were not wholly distinct. In a later publication Simpson (1928) reverses this decision and finds that the two groups were distinct and that the zalambdodonts were derived from a group closer to the Deltatheridiidae. This then is the last pronouncement of the student who has written more on the subject in recent years than any other author.

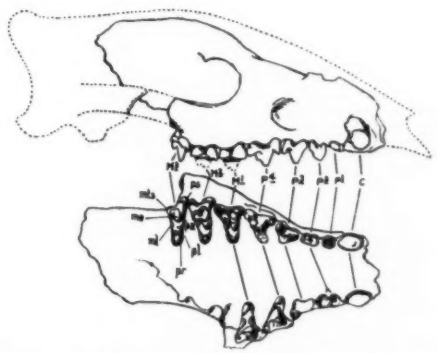


FIG. 1.—*Puercolestes simpsoni* Reynolds, n. sp., holotype, reconstruction of profile skull, and palate in detail, ×1.2.

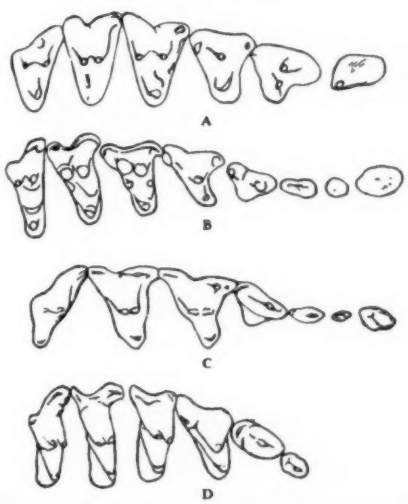


FIG. 2.—Diagrammatic representation of the upper right dentition of A, *Didelphodus;* B, *Puercolestes;* C, *Deltatheridium;* D, *Paleoryctes.*

The skulls described in the present paper enter the above discussion at this point, and in the following pages I shall strive to set forth the evidence at hand gleaned from a careful study of the literature, from personal study of these specimens at the American Museum of Natural History, and finally as a result of repeated discussion with Doctor Simpson and the late Professor William Diller Matthew, of the University of California.

Acknowledgments.—I recall with gratitude the assistance given me at the University of California by Professor Matthew, who studied *Puercolestes* when it was as yet inadequately prepared. Also Dr. George Gaylord Simpson, of The American Museum of Natural History, New York, is deserving of my deep appreciation for his advice and helpful suggestions during the preparation of this paper. I wish further to acknowledge the photographs given me by the American Museum of Natural History which are shown in fig. 2. Finally I wish to thank Dr. C. L. Camp, of the Museum of Paleontology at the University of California, for his help and the loan of material from that institution.

The manuscript of this paper was received by the editor June 19, 1935.

Location.—The Puerco formation, the lowermost member of the Paleocene sediments of northwestern New Mexico, is confined to the southwest margin of a great structural basin. Fossils are most abundant in the Arroyos Kimbetoh (Kinebetoh), Ojo Alamo, and Eduardo or Bitonitsoseh ("Nameless," Granger and Sinclair).

The skulls described in this paper are from Arroyo Eduardo, which locality corresponds to the larger area called "Loc. 7" by Granger and Sinclair, and the exact spot is shown in their Plate XVI.

SYSTEMATIC DESCRIPTIONS

INSECTIVORA

DELTATHERIDIIDAE

PUERCOLESTES Reynolds. n. gen.

PUERCOLESTES SIMPSONI Reynolds, n. sp.

Plate 25, figures 1–3

Type: St. Louis Univ. 101, palate.

Horizon and locality: Puerco formation, lower Paleocene, San Juan Basin, New Mexico.

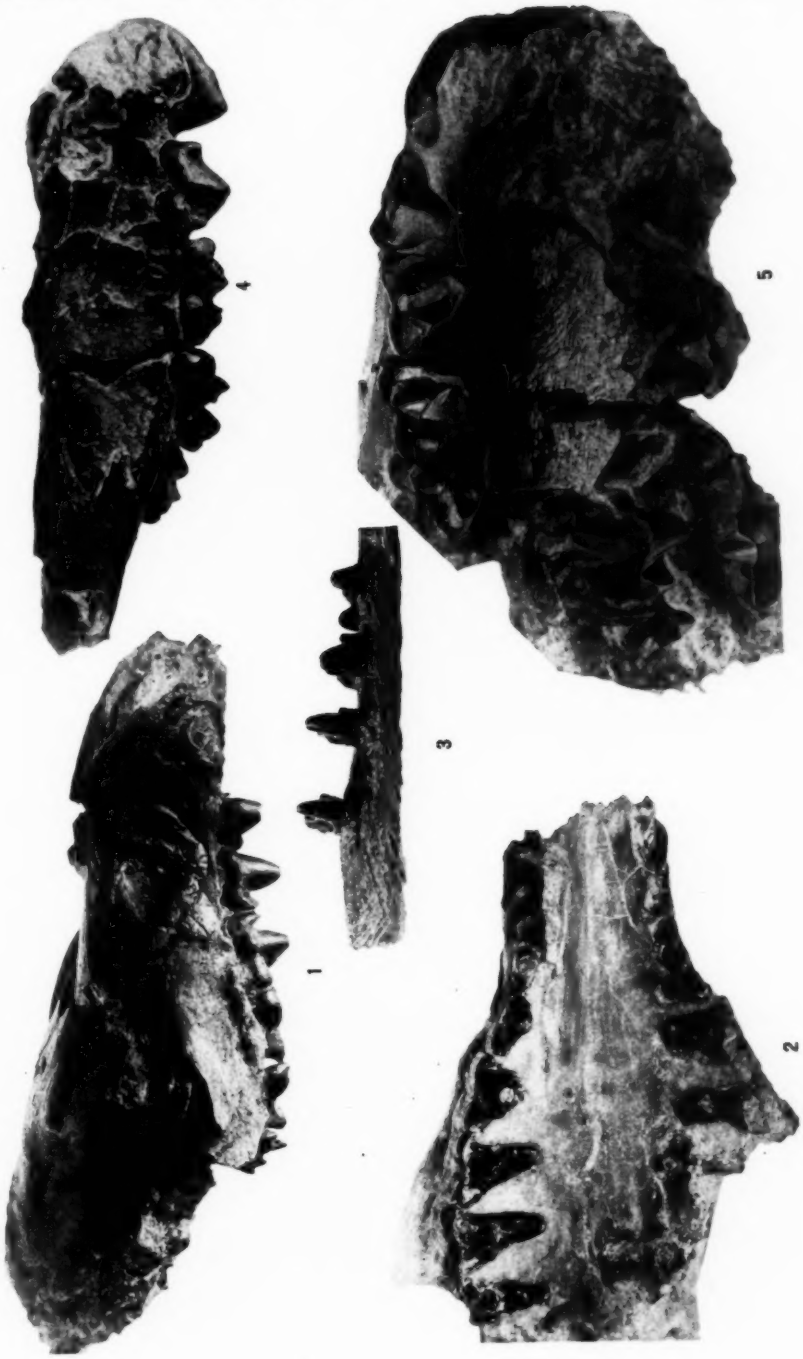
Dentition: All teeth on right maxillary border preserved with exception of first premolar and canine; left border with fourth premolar and first molar only; incisors lost. Lower dentition partially preserved; originally trigonids engaged with upper teeth, mandibles and talonids shorn away, and fractured bases of trigonids projected above level of upper tooth-row. These were removed from matrix and fitted into a dental-wax mold prepared from the specimen before removal; Pl. 25, fig. 3, shows mounted teeth.

Lower dentition: Talonids high relative to heels, perhaps approaching height of this structure in *Paleoryctes*, and per-

EXPLANATION OF PLATE 25

FIGS. *1–3*—*Puercolestes simpsoni* Reynolds, n. sp., holotype, ×3, St. Louis Univ. Mus. 101; Puerco formation, San Juan Basin, New Mexico. *1*, Lateral view; *2*, palate; *3*, fractured lower teeth mounted in dental wax in natural position. (p. 204)

4, 5—*Escatepos campi* Reynolds, n. sp., holotype, ×3, St. Louis Univ. Mus. 118; Puerco formation, San Juan Basin, New Mexico. *4*, Lateral view; *5*, palate; fractured mandible with tooth row imbedded in palate. (p. 207)



Reynolds, Paleocene Mammals

UNIV. OF MICH.

haps indicating zalambdodont affinities. Certainly trigonids would be much higher than in *Didelphodus*, formerly regarded as a leptictid, later considered a relative of the Deltatheridiidae by Simpson (1928). P_4 offers little evidence except that it seems slightly more robust, a character not observable from Pl. 25, fig. 3, but somewhat indicated under the binocular microscope. Reduction of paraconid, on the other hand, would seem to point toward leptictid trends. Here again is found that peculiar confusion of zalambdodont and leptictid affinities seen in *Deltatheridium*, of the Mongolian Cretaceous, and *Didelphodus* of the North American Eocene.

Upper cheek teeth: Upper series well-preserved, showing rather wide marginal shelf, a little less than one-third of total width of molars themselves.

Fourth premolar without shelf but with well-developed stylar cusps. Paracone and metacone not connate, as in *Paleoryctes*, a pronounced zalambdodont; yet in close relationship as contrasted with other Tertiary forms, not undoubted zalambdodonts. Third premolar not advanced as far in its degree of molarization as one might expect in a primitive trituberculate with zalambdodont trends, but nevertheless a robust tooth with central, anterior, and posterior cuspules well-defined.

Fourth premolar on right maxilla what damaged, protocone having been broken away; paracones and metacones not preserved, either broken away, or worn down during life. It is somewhat difficult to interpret the degree to which these central cusps have tended to merge, but careful study under the binocular microscope would seem to indicate that their fractured bases were about as shown in fig. 1.

Third, or last, molar surprisingly aberrant in structure; specifically the degree of transverse shear in a form as complex as *Puercolestes*.

First premolar a simple cutting tooth, present in only one tooth-row, the right. Left tooth row contains no alveolus for this tooth—not such an unusual occurrence in animals fossil or modern; little can be concluded from this omission of nature.

Paraconules and metaconules of these cheek teeth, although present, are not very well developed; when observed under magnification, paraconule larger than metaconule. Absence of any trace of hypocone on molars an extraordinary feature.

Measurements of the skull of *Puercolestes* are shown in the following table.

Measurements in Millimeters of the Skulls of Puercolestes simpsoni (1) *and* Escatepos campi (2)

	(1)	(2)
Length, pmx. border to parocc. process	25.0	—
Length, pmx. border to post-palat. crest	23.7	—
Length, upper teeth, C-M^2 inclusive	21.0	—
Length top of skull, pmx. to occ. crest	37.0	—
Width across zygomatic arches	19.1	19.0
Width of palate including M^1	14.5	14.0
Width of postorbital constriction	12.1	—
Width between orbits	16.0	—
Width of muzzle at infraorbital foramen	8.0	12.0
Width of brain case (at zygomatic process)	10.0	—
Distance from ant. rim of orbit to i.o.f.	7.0	—
Length upper cheek teeth, P^1–M^2	7.0	12.0
I, anteroposterior diameter	2.5	—
I, transverse diameter	1.9	—
P^1 anteroposterior diameter	3.0	—
P^1 transverse diameter	2.0	—
P^2 anteroposterior diameter	1.9	4.0
P^2 transverse diameter	1.1	1.1
P^3 anteroposterior diameter	3.4	3.6
P^3 transverse diameter	1.7	2.5
P^4 anteroposterior diameter	3.4	4.0
P^4 transverse diameter	4.0	3.6
M^1 anteroposterior diameter	3.4	4.0
M^1 transverse diameter	4.0	3.6
M^2 anteroposterior diameter	3.3	3.6
M^2 transverse diameter	4.6	—
M^3 anteroposterior diameter	2.6	—
M^3 transverse diameter	4.1	—

Relationships.—After much study and comparison of the tooth-structure of *Puercolestes*, it seems to me that the little skull is closest in structure to two forms; to *Didelphodus*, of the Eocene, on the one hand, and *Deltatheridium*, of the Mongolian Cretaceous, on the other. The sum of the differences of *Puercolestes* from these genera is adequate to establish it as a new genus.

Puercolestes resembles *Didelphodus* in the general cut of the teeth, the absence of a hypocone, the prominent marginal shelf in the upper molars, the rather centrally located paracone and metacone, and the prominent single internal cusp, the protocone. Some striking differences appear. P^3 of *Puercolestes* is not far progressed, whereas *Didelphodus* shows an internal spur of great prominence, thereby complicating the tooth. Again, M^3 is pronouncedly transverse; this I regard as merely an aberrancy. The paracones and metacones of the molars are slightly more external in *Puercolestes;* this feature I regard likewise as an aberrancy in the new genus.

Puercolestes resembles *Deltatheridium* in some respect still more closely than it resembles *Didelphodus*. The hypocone is absent, the prominent marginal shelf is present, the stylar cusps are greatly emphasized, and the tendency to a confluence of the paracones and metacones is apparent. P^4 of *Deltatheridium* manifests, however, less tendency to molarize than in *Puercolestes*, but the degree of confluence of paracones and metacones is much greater in *Deltatheridium*. P^3 is relatively a simple tooth.

Before proceeding with further comparisons it will be well to give a brief resume of the taxonomic position of *Didelphodus* and *Deltatheridium* as conceived by Simpson. Simpson (1928) considered the Deltatheridiidae to be structurally "in a central position, ancestral to the creodonts and to many or all of the Dilambdodont Insectivores and possibly also to other orders." He states further that the "divergence from the Zalambdodonts is really less in this family than in the Zalambdalestidae." He regards *Didelphodus* and *Deltatheridium* as having definite kinship. At least it could be said that "*Deltatheroides* had no known character that would exclude it from the ancestry of *Didelphodus*."

Now I have shown that *Puercolestes* possesses points of resemblance to these two genera to a high degree. In point of time it stands midway between them, the one from the Cretaceous, the other from the Eocene. Hence the appearance of this little skull at the base of the Puerco formation does much to bear out Simpson's judgment as briefly recounted above, a judgment he arrived at without the evidence of the Puerco form. The points of difference between the Cretaceous and Puerco skulls are merely such as would indicate a more advanced development in the Puerco form, with some aberrancy, just as one would expect; having in mind the time-lapse between the two ages.

I therefore refer *Puercolestes simpsoni* to the Deltatheridiidae, a group of peculiar interest, inasmuch as it, of all known groups of mamals, "stands closest to the common point of divergence of all placental mammals."

The family Deltatheridiidae Gregory and Simpson contains, following Simpson, the genera *Deltatheridium*, *Deltatheroides*, *Hyotheridium*, *Didelphodus*, *Phenacops*, and *Puercolestes*, "provisionally united under a single family." It will be of interest here to quote further: "The Creodont and Zalambdodont lines may tentatively be visualized as diverging at a time somewhat earlier than that of Djadokhta Formation and the Deltatheridiidae as arising in or near the base of a focal Asiatic protocreodont group, within the order Insectivora."

Comparison of Puercolestes *with* Paleoryctes.—A casual study of the tooth structure of the various forms shown in fig. 2, suggests that *Paleoryctes* is really close to *Puercolestes*. The Torrejon form has often been referred to as a typical zalambdodont. Indeed, most of the characters listed as peculiar to that group

seem to be found in *Paleoryctes*. Sufficient zalambdodont characters are evident in *Puercolestes* to make one suspect a direct relationship.

The development of marginal shelves in the two forms under consideration is more pronounced than in the other forms figured in fig. 2. Again the general contour of this structure is very much alike in the several forms, probably more pronounced in P^3 of *Paleoryctes*. The protocone draws the tooth into a sharp angulate pattern strikingly similar in the two forms. In M^3 the parastyle is more pronounced in *Puercolestes*, being almost suppressed in the other genus. The difference is of little consequence, however, since little can be concluded from the vagaries in development of last molars, as has been observed before. The degree of twinning of paracone and metacone is more pronounced, of course, in *Paleoryctes*, but the difference is slight. The fourth pre-molar is more developed in *Puercolestes*,

I think that sufficient details have been pointed out thus far to indicate that *Puercolestes* is in my mind the most likely ancestor for *Paleoryctes* that the bleak sediments of the San Juan, or any other Paleocene horizon, has revealed at the present time.

Creodonta

Oxyclaeninae

Genus Escatepos Reynolds, n. gen.

Escatepos campi Reynolds, n. sp.

Plate 25, figures 4, 5

Type: St. Louis Univ. 118, palate.

Horizon and locality: Puerco beds, lower Paleocene, New Mexico.

Condition of preservation of *Escatepos* not as good as that of previously described specimen. Right maxilla retains five teeth, two molars and three premolars; left maxilla, the fractured remains of three teeth. None of the roofing bones of the skull preserved; the entire occipital region absent. Mandible apparently collapsed in center of palate at time of fossilization and cemented there. Complete recovery of the lower teeth impossible.

Identification of fourth premolar, of greatest importance, is a very involved task in this specimen. The whole series I regard as first, or milk dentition because of frail, flaky construction. If this is correct, third, or last, molar not present either because not yet erupted or because broken away in the specimen; last molar actually seen is second molar; tooth in front of this is first molar and immediately anterior is fourth premolar. This is my interpretation of the tooth series after careful study of the specimen. The late Professor Matthew, who also examined the specimen, was of the same opinion.

Casual examination of this fourth premolar shows it strikingly different from tooth immediately anterior and from tooth behind. Much more complex than dp^3 and much less complex than M^1; marginal shelf of dp^4 poorly developed as compared with M^1; paracone and metacone likewise less prominent; protocone draws tooth out to a sharp angular pattern contrasted with broad, square outline of M^1. If these observations are correct molarization of P^4 is rather far advanced.

Measurements of the skull of *Escatepos campi* are shown in the table on p. 205.

Affinities of Escatepos.—Like *Puercolestes*, *Escatepos* possesses characters proper to several groups, but unlike *Puercolestes* it lacks sufficient of these characters to permit assignment with certainty. The only statement I could make with assurance about its affinities is that its place is probably with some primitive creodont group of the Paleocene, perhaps the Oxyclaeninae. Otherwise I should consign it to the limbo of "*incertae sedis*."

If the specimen really has a molariform P^4, as my interpretation of the teeth would seem to indicate, one might suspect it of relationship with some primitive insectivore stock, hardly with any leptictid. On the whole it does manifest

a creodont dentition, but some of these primitive forms have been proved to be insectivores when further skeletal evidence was available. It is within the bounds of possibility that such may prove to be the case with this specimen. However, its structure does not agree with that of any of the pseudo-oxyclaenines to a degree that would warrant placing *Escatepos* in their category.

One looks forward with expectancy, assured by the presence of this primitive fossil in the lowermost Puerco, to the recovery of more material in the same locality that may shed light on the bridge between the insectivores and creodonts. I have always thought it would be found at the Cretaceous-Paleocene border, despite the fact that *Gypsonictops* is regarded as a Cretaceous insectivore, even a doubtful lepticid. Of course, if *Escatepos* on further evidence should turn out to be an insectivore, the possibilities that *Gypsonictops* is a true insectivore are greatly enhanced; in this event *Escatepos* would prove to be the last word in the argument, hence the name I have given the specimen—"the last word," És(ch)atos—Épos(ἔσχατος-ἔπος).

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NEW CAMBRIAN BRACHIOPODS FROM ALASKA

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ABSTRACT

The new genus *Arctohedra*, containing two new species, is proposed. New features of *Nisusia* Walcott are recorded, and a new species is described.

The material described below was collected by J. B. Mertie, Jr., of the U. S. Geological Survey, from a Middle Cambrian limestone, 3 miles northeast of Eagle, Alaska. Two genera are included, one new and the other, *Nisusia* Walcott, a genus that has been only imperfectly understood since its establishment. The specimens are remarkable for their fine preservation, having been sufficiently silicified to permit them to be etched free from the entombing matrix, and therefore permit determination in considerable detail of the structure of the new genus and afford opportunity to clear up uncertain points on *Nisusia*.

All of the types are in the collections of the U. S. National Museum.

The paper is published with the permission of the Secretary of the Smithsonian Institution. The manuscript was received by the editor of the Journal July 1, 1935.

SYSTEMATIC DESCRIPTIONS

ARCTOHEDRA Cooper, n. gen.

Etymology: ἄρκτος, the Great Bear (the north); ἕδρα, a seat.

Shell small; exterior like that of the Devonian genus *Skenidium*. Ventral valve pyramidal, interarea long, broad; dorsal valve flat or gently convex, with a gentle median sulcus. Inside ventral valve a concave plate (free spondylium) is attached to inner central edge of delthyrial margins; pallial sinuses straight, directed anterolaterally. Inside dorsal valve a strong notothyrial platform and median ridge; brachial processes long, blade-like; no cardinal process.

Genotype: *Arctohedra minima* Cooper, n. sp.

When the interesting little shells here described as a new genus were discovered, the writer, on casual examination, believed tham referable to *Protorthis*. The presence of a free spondylium in the ventral valve suggested this assignment, but close comparison of the dorsal valve with that of *Protorthis* convinced him that the genera are distinct.

Protorthis has been imperfectly known because of the poor preservation of the shells referred to the genus, all known to the writer occurring in the form of internal and external impressions. The shells are very thin and are often badly crushed. The exteriors of *Protorthis* and *Arctohedra* are not very different, the latter differing chiefly in the more pyramidal form of the valve and the greater length of the interarea. The pyramidal form of the Alaskan shells is apparently not due to youthfulness, because in one of the larger specimens the shell

is very thick and the recesses under the free spondylium are mostly filled with shell substance, indicating a specimen in old age. Most of the other shells show more or less deposition under the spondylium.

The internal structures of the ventral valves of the two genera appear to be very much alike. The only difference discernible—which may be entirely due to the limitations of the material—is the greater length and strength of the free spondylium in the Alaskan species. Pallial sinuses have not been noted in *Protorthis*, but in one specimen of *Arctohedra* the course of the main trunks is clear. From the right side of the spondylium, as seen from the inside (Pl. 26 figs. 8, 11), a main sinus extends anterolaterally. This trunk originates under the spondylium at about the position that is occupied by the right diductor impression in other brachipods, the usual position for the main trunks of the pallial system in the ventral valve of all orthoid, clitambonitoid, or syntrophoid brachiopods known to the writer. Definite muscular impressions are indicated in one specimen on the posterior surface of the spondylium. As indicated by this specimen, the diductor tracks are linear impressions on the plate along the side of the delthyrium, where they form impressed tracks. The adductor track occupies the center of the plate and is rather strongly impressed. The position of the various tracks is visible at the front of the plate. The adductor track is indented at the front, but the portion on the plate occupied by the diductor tracks is extended anterior to the front part of the middle of the plate. In most of the other specimens no muscular marks or tracks were visible, but the surface of the plate is marked by faint concentric wrinkles, which may represent progressive growth-lines of the spondylium. Since none of the specimens shows evidence of muscular impressions on the floor of the valve under the spondylium, and the one specimen does show clear evidence of muscular tracks on the posterior surface of the spondylium, it is concluded that the free plate served as the seat of muscular attachment. This is probably the case in *Protorthis* also, but the point cannot be conclusively demonstrated.

In the particular shells under consideration the point of generic, and perhaps also family departure, is to be seen in the dorsal valve. The cardinalia of *Protorthis* are rudimentary, reminding one of those of *Nisusia* more than of any other Cambrian brachiopod. The notothyrial cavity is rather deeply excavated and there is scarcely any development of a notothyrial platform. In *Arctohedra*, on the other hand, the notothyrial cavity is completely filled by a great swelling of shell substance that serves as a very efficient support to the long and straight brachial processes. In *Protorthis* the brachial processes are short and rudimentary. The median ridge of *Arctohedra* is rather well developed and rather strongly elevated. Adductor impressions are distinctly visible on either side of the median ridge, but their individual shapes cannot be definitely determined. They appear to be elongate. In *Protorthis* the median ridge is rudimentary, if present at all, and muscular scars are very difficult to determine. A trace of a convex chilidium covers the posterior part of the notothyrium in one dorsal valve of *Arctohedra minima* (Pl. 26, fig. 14).

ARCTOHEDRA MINIMA Cooper, n. sp.

Plate 26, figures 1–5, 10, 12, 14, 15

Shell minute, wider than long; pyrammidal in profile, ventral valve strongly pyramidal, dorsal valve slightly convex. Surface of both valves finely multicostellate. Dorsal valve marked by a wide, rather strong median sulcus. Inside ventral valve free spondylium shallow.

Measurements: Ventral valve, 1.0 mm. long, 2.5 mm. wide; dorsal valve, 1.1 mm. long, 2.4 mm. wide.

Horizon and locality.—Middle Cambrian, 3 miles northeast of Eagle, Alaska.

Syntypes.—U. S. Nat. Mus. 91900, *a–e.*

ARCTOHEDRA MERTIEI Cooper, n. sp.

Plate 26, figures 6–9, 11, 13, 16–21

This species is distinguished from *A. minima* by its larger size; longer interarea, which may be strongly apsacline or procline; proportionately longer free spondylium; and more concave plate. Externally *A. mertiei* is marked by numerous strong, rounded costellae which are wider than the interspaces.

Measurements: Ventral valves, 3 mm. long, 5 mm. wide; 2 mm. long, 3.5 mm. wide. Dorsal valve, 2 mm. long, 3(?) mm. wide.

Horizon and locality.— Middle Cambrian, 3 miles northeast of Eagle, Alaska.

Syntypes.—U. S. Nat. Mus. 91901, *a–c*.

Genus NISUSIA Walcott, 1905

Nisusia WALCOTT, *1905*, U. S. Nat. Mus., Proc., vol. 28, p. 247; *1912*. Cambrian Brachiopoda, U. S. Geol. Survey, Mon. 51, p. 725.—SCHUCHERT and COOPER, *1932*. Peabody Mus. Nat. Hist., Mem., vol. 4, pt. 1, pp. 44.

Nisusia has been known hitherto only from specimens enclosed in matrix or from internal and external impressions. Although some of the material is good,

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EXPLANATION OF PLATE 26

All specimens shown, except originals of figs. 27, 33, and 39, are from Middle Cambrian lime stone, 3 miles northeast of Eagle, Alaska. All are in the U. S. National Museum.

FIGS. *1–5, 10, 12, 14, 15—Arctohedra minima* Cooper, n. gen. and sp., syntypes. *1*, Exterior of dorsal valve showing median sulcus, ×10, U.S.N.M. 91900; *2*, somewhat better preserved dorsal exterior, ×6, U.S.N.M. 91900; *3, 15*, interior of a ventral valve showing the free spondylium, ×5, U.S.N.M. 91900*b*; *4*, exterior of ventral value, ×6, U.S.N.M. 91900*c*; *5, 10, 12*, interior and exterior of dorsal valve, ×10, exterior, ×10, exterior, ×6, U.S.N.M. 91900*d*; *14*, interior of dorsal valve showing cardinalia, ×10, U.S.N.M. 91900*e*. (p. 211)

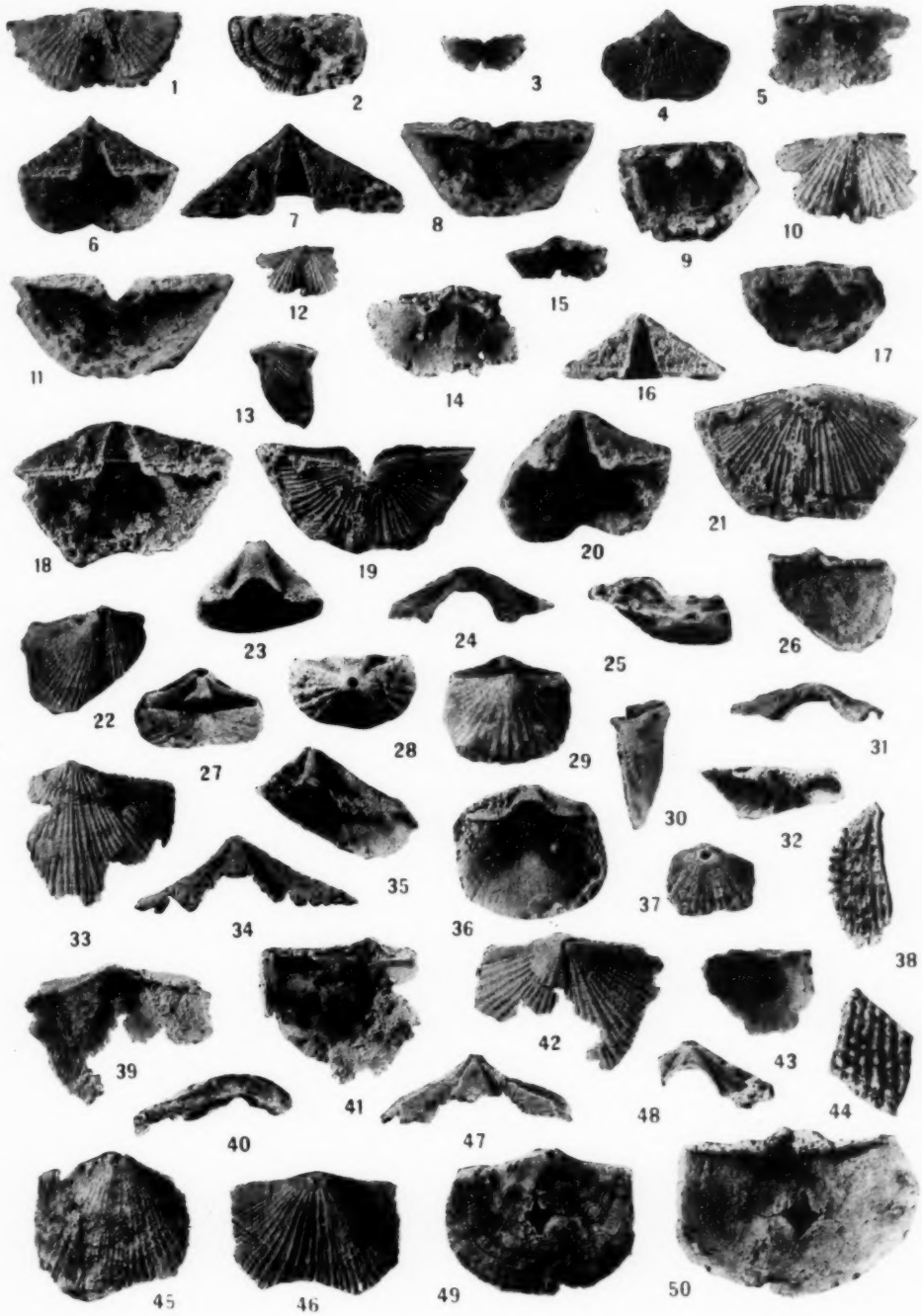
6–9, 11, 13, 16–21—Arctohedra mertiei Cooper, n. gen. and sp., syntypes. *7, 8, 11, 13, 18, 19*, Ventral valve, U.S.N.M. 91901; *7*, posterior view, ×6, showing interarea and delthyrium; free plate clearly visible; *8*, interior, ×5, showing pallial sinus on right side of free spondylium; *11*, interior, ×6, showing edge of free plate and portion of one of the pallial impressions on right side; *13*, side view, ×4; *18*, cardinal view, ×6, tilted to show surface of free spondylium; *19, 21*, exterior views, ×6. *6, 16*, Posterior and cardinal views of ventral valve, ×6, U.S.N.M. 91901*a*. *20*, Ventral valve, ×6, with its unsupported plate, U.S.N.M. 91901*b*. *9, 17*, Interior of dorsal valve, ×6, showing cardinalia indistinctly; in *17* specimen is tilted to show interarea and brachiophores; U.S.N.M. 91901*c*. (p. 212)

22, 23, 25, 26, 28, 30–32, 34, 35, 37, 38, 43, 44, 46, 48–50—Nisusia borealis Cooper, n. sp., syntypes. *22, 26, 30, 35*, Incomplete ventral valve, U.S.N.M. 91903, showing strongly arched deltidium and absence of dental plates; *22*, exterior, *26*, interior, *30*, side view, ×1½; *35*, cardinal view, ×2. *23, 28*, Cardinal and apical views of young ventral valve showing deltidium and large apical foramen, ×3, U.S.N.M. 91903*a*. *25, 48*, Apical view, ×2; cardinal view, ×1½, of ventral valve showing deltidium and rounded edge of palintrope, U.S.N.M. 91903*c*. *31, 32*, Cardinal and interior views, ×2, of posterior part of dorsal valve showing long, deep sockets and short brachial processes, U.S.N.M. 91903*b*. *34, 49, 50*, Large ventral valve, U.S.N.M. 91903*d*; *34*, cardinal view, ×1½; *10*, exterior, ×1; *50*, interior, ×1½, showing rudimentary dental plates. *37*, apical view of small specimen showing foramen, ×3, U.S.N.M. 91903*e*. *38, 44*, Side view, ×3; front view, ×4, of fragments of shell showing the spines, U.S.N.M. 91903*g, h*. *43*, Dorsal interior, ×2, U.S.N.M. 91903*f*; *46*, dorsal exterior, ×1½, U.S.N.M. 91903*i*. (p. 214)

24, 36, 45—Nisusia sp.; *24, 45*, cardinal and ventral views ×2, of ventral valve showing the deltidium, U.S.N.M. 91902; *36*, ventral interior, ×3, U.S.N.M. 91902*a*. (p. 214)

27, 29—Nisusia sp., cardinal and dorsal views of a small complete individual, ×2, U.S.N.M. 91904; Middle Cambrian, Pole Creek, Madison County, Montana. (p. 214)

33, 39–42, 47—Nisusia festinata (Billings), hypotypes, ×2; Lower Cambrian, Shady dolomite, ¾ mile east-northeast of Austinville, Virginia; *33, 40, 41*, exterior, cardinal, and interior views of dorsal valve, U.S.N.M. 91905; *39, 42, 47*, interior, exterior, and cardinal views of ventral valve U.S.N.M. 91905*a*. (p. 214)



Cooper, Cambrian Brachiopods

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such as that from York, Pennsylvania, a number of important structures in the anatomy of the genus have remained obscure or unknown. The nature of the foramen has been in doubt. From the fact that the beak of most specimens of the genus observed by the writer and others was broken, and from the fact that the internal fillings of the ventral valves of specimens in the leached limestones from York clung to the matrix by the beak, it was deduced that the apex of *Nisusia* must be open. This deduction is now definitely confirmed. The silicified specimens from Alaska and Virginia show an open foramen in all stages of the development of the shell (see Pl. 26, figs. 22, 27, 28). The surprising features are its large size and its position, i.e., the apices of the beak and deltidium are both excavated by the foramen. In appearance, then, adult *Nisusia* has very much the same exterior as the young of such strophomenoid genera as *Strophomena* and *Leptaena*. No other Cambrian genus known to the writer has such a structure. In *Billingsella*, which has an apical foramen, the body of the valve itself is not excavated by the foramen, the latter piercing the deltidium only. The foramen of *Nisusia* is primitive, but the genus is so far removed from the Upper Cambrian and later brachiopods that any connection between them must be remote indeed.

The deltidium of *Nisusia* is a strongly arched plate attached to the sides of the delthyrium and strengthened by deposition of callus within the delthyrial cavity. The interesting feature of the deltidium is that it fails to close the opening between the valves, for although the foramen is well-marked and large there is still a great gap between the valves. This gap may have been, and probably was, covered by a non-calcified integument. Owing to the fact that the foramen is open in all stages of the genus represented in the collection described herein, it is concluded that during life the pedicle emerged from the foramen.

No definite chilidium was seen on any of the specimens. The nearest approach to such a structure was observed in specimen 91903*b* (Pl. 26, fig. 31), in which the inner edges of the brachial process unite postero-dorsally in front of the beak to form a flattened plate on the ventral side of the beak.

Another feature of the ventral valve which has not before been perfectly clear is its internal structure. It is possible on the basis of this fine Alaskan material to say definitely that dental plates are wanting in most specimens and in others are present only in a rudimentary state. Absence of dental plates in the higher brachiopods is a specialization, but in the present genus it is a mark of very primitive character. None of the specimens indicate muscular or pallial marks clearly enough for description.

The cardinalia of the dorsal valve present a very primitive aspect in the shortness of the brachial process and in the absence of a cardinal process and a strong median ridge. The brachial process is triangular in outline, with the apex of the triangle at the beak and the base of the triangle, which is rounded, near the edge of the palintrope; the outer edge of the triangle is cemented to the under edge of the palintrope. The brachial process forms a shallow trough, open posteriorly and visible from the apex of the base, deepening toward the base; this trough forms the socket. The concave brachial process is supported along its anterior surface by a deposition of shell substance united to a median apical thickening, which forms a rudimentary notothyrial platform.

Traces of the dorsal adductor muscle scars are visible in front of the rudimentary notothyrial platforms. Several specimens show a rudimentary median ridge just anterior to the notothyrial platform and, on each side of the ridge, an elongate impression. The same muscular elements are visible in "*Finkelnburgia*" *noblei*, which is clearly a *Nisusia* of Middle Cambrian age.

NISUSIA BOREALIS Cooper, n. sp.

PLATE 26, figures 22, 23, 25, 26, 28, 30–32, 34, 35, 37, 38, 43, 44, 46, 48–50

Shell rather large, unequally biconvex, ventral valve having the greater convexity; cardinal extremities obtuse or forming approximately a right angle. Surface multicostellate; costellae unequal in size and increasing chiefly by implantation; in a large dorsal valve (Pl. 26, fig. 46) 10 costellae in the space of 5 mm. at the front of the valve.

Ventral valve subpyramidal in profile, with long interarea and pointed beak; a shallow sulcus extends from the umbo to middle of the valve, where it is lost. In profile posterior half of valve rather flat, front half rather swollen. Flanks of shell rather gently concave.

Umbonal region of dorsal valve gently swollen; at one-third to one-half length of valve from beak, shell depressed to form shallow but wide sulcus. Region bounding sulcus gently swollen; slopes leading to cardinal extremities gentle.

Horizon and locality.—Middle Cambrian, 3 miles northeast of Eagle, Alaska.

Syntypes.—U. S. Nat. Mus. 91903, *a–h.*

Discussion—This species most closely resembles *Nisusia festinata* (Pl. 26, figs. 33, 39–42, 47) in the possession of a median sulcus on the ventral valve, but differs in that the ventral valve is more swollen and the sulcus less prominent. The sulcus on the dorsal valve of *N. borealis* is wider and deeper than that of the dorsal valve of the *N. festinata;* and the costellae are a little stronger. The spines are not well preserved on any of the whole specimens of *N. borealis*, but two fragments of shell retain them and show them to be much more numerous and more closely spaced than those of *N. festinata.*

NISUSIA sp.

Plate 26, figures 24, 36, 45.

A second species of *Nisusia* is present in the material, but the specimens are too poor to warrant the use of a new name. The species, as indicated by the ventral valves only, is distinguished from *N. borealis* by a strongly and rather evenly convex valve. The deltidium of this form covers less of the delthyrium than that of *N. borealis.*

Horizon and locality.—Middle Cambrian limestone, 3 miles northeast of Eagle, Alaska.

Figured specimens.—U. S. Nat. Mus. 91902,*a.*

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A DEVONIAN FLORA FROM KENTUCKY

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ABSTRACT

The flora of the basal part of the Linietta clay of Foerste at a locality near Junction City, Kentucky, comprises 24 species assigned to 18 genera; of these, 15 species and 5 genera are new. All of the material represents stems and other parts preserving the structure. Paleontologic and stratigraphic evidence indicates correlation of the Linietta clay with the upper part of the New Albany shale (Upper Devonian) of Indiana.

This paper is a preliminary account of a well-preserved flora from the base of the beds in central Kentucky described by Foerste as "Linietta clay." Only summary analyses of new or heretofore imperfectly known species are given, and the statements concerning age and local correlation in the belt of outcrop of the several black shale formations around the Cincinnati arch are purposely made brief. In later papers all matters pertaining to this flora will be discussed in detail.

STRATIGRAPHIC CONSIDERATIONS

The flora here treated was collected at a locality near Junction City, Boyle County, Kentucky. The horizon yielding the plants is the basal bed of the Linietta clay of Foerste (1); furthermore, the station is identical with that designated by Foerste as the type section of his Linietta.

Briefly, the local stratigraphic sequence is as follows: Overlying a Middle Devonian cherty limestone (Boyle limestone) in central Kentucky there is a variable thickness (30 to 100 feet) of black shale. In Boyle County the basal member of the black shale (New Albany) is a limy sandstone with intercalated lenses of shale, referred to as the Duffin layer (Tully fauna); succeeding this are about 35 feet of highly carbonaceous and bituminous shale. The next overlying strata consist of about 40 feet of blue-green clay shales (the Linietta clay of Foerste), which are followed by sandstones carrying a typical Osage (Mississippian) fauna (New Providence). The basal 2 feet of the blue-green clay shales contain numerous phosphatic nodules, which have yielded the flora here described and in addition a fauna consisting of *Lingula melae*, *Spathiocaris*, *Solenocaris*, *Colpocaris*, fragments of goniatites, radiolarians, and fish bones. The blue-green clays above the nodule zone are barren of fossils except for *Taonurus caudi-galli*, which occurs in occasional sandy lenses. Elsewhere there are lenses of crinoidal limestone in this upper portion of the clay, but in Boyle County these lenses have not been noted.

The contact between the black

New Albany shale and the overlying blue-green clay shale is very sharp. In the past the opinion has been expressed that this line marks the boundary between the New Albany shale and the New Providence shale, to which the whole of Foerste's Linietta has been attributed (2). Evidence at hand, however, now demonstrates that the basal nodule-bearing bed of Foerste's Linietta clay is correlative with the uppermost beds of the typical New Albany shale, as developed in the vicinity of New Albany, Indiana. The crustacean fauna mentioned above occurs at both localities; the floras of the two localities have a number of species in common and indicate contemporaneity; and purely stratigraphic evidence, involving tracing of the nodular horizon, strongly suggests this relationship. In consequence, it is suggested that the upper boundary of the New Albany shale in Boyle County (and perhaps in other portions of central Kentucky as well) be drawn at least as high as the upper limit of the occurrence of plant-bearing phosphatic nodules in the blue-green clay shales (Linietta clay of Foerste). At any rate, there is ample evidence indicating decisively that the flora here described is New Albany (Upper Devonian) in age, and not younger, as Scott and Jeffrey (3) have suggested.

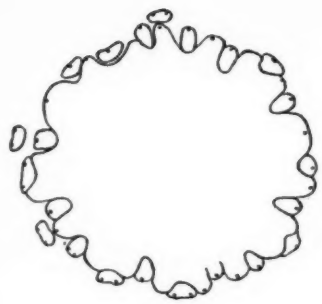
Pteridospermae
Calamopityeae

The most abundant plant remains in the Linietta clay are those referable to the Calamopityeae. In addition to *Calamopitys americana* Scott and Jeffrey, *Kalymma grandis* Unger, and *Calamopteris hippocrepis* Scott and Jeffrey, specimens have been obtained which are here designated *Kalymma lirata* Read, n. sp., *K. resinosa* Read, n. sp., *K. auriculata* Read, n. sp. *Diichnia kentuckiensis* Read, n. gen. and sp., *Calamopitys foerstei* Read, n. sp., and *Stenomyelon muratum* Read, n. sp.

The Calamopityeae is one of the largest natural families of Devonian and Mississippian plants known. As now understood, it includes the genera *Calamopitys* Unger, *Eristophyton* Zallesky, *Endoxylon* Scott, *Bilignea* Scott, *Kalymma* Unger, and *Calamopteris* Unger. To this series the writer also refers *Diichnia* Read and *Stenomyelon* Kidston. It is desirable to discuss briefly the relationships of these last-named genera to those genera previously included in the family.

Diichnia Read, n. gen., may be defined as including plants with stems of various sizes containing a mixed pith. The pith is distinctly five-angled in the genotype, and eccentrically mesarch xylem strands are situated at these angles and are separated from the secondary wood by a few cells of parenchyma. The secondary xylem is a relatively limited cylinder and is traversed by wide rays; no pitting is known. The cortex is similar to that in *Eu-Calamopitys*. The leaf trace is dilacunar, two strands from adjacent angles of the pith passing outward and dividing to form a polydesmic petiole of the *Kalymma* or *Calamopteris* type. Genotype: *D. kentuckiensis* Read, n. sp.

Stenomyelon Kidston is characterized by a distinctly three-angled central "mixed pith," which is in this case almost entirely primary xylem; by a zone of secondary wood traversed by broad rays; by a one-third divergence of the leaves; and by a polydesmic leaf trace that is developed from a single mesarch or exarch bundle. Protoxylem is clearly differentiated only in connection with leaf-trace departure. The leaf trace is derived from the angles of the pith in a protostelic manner, a natural conse-



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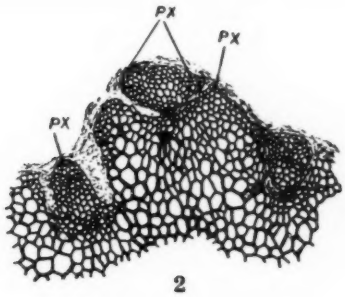

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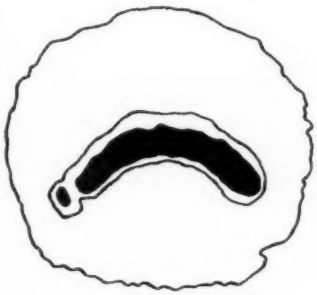

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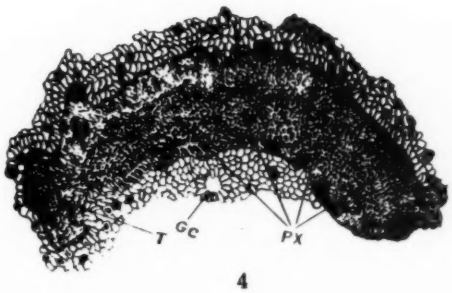

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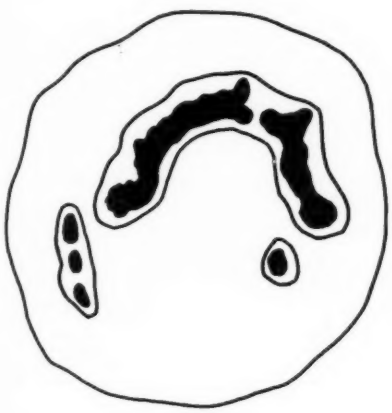

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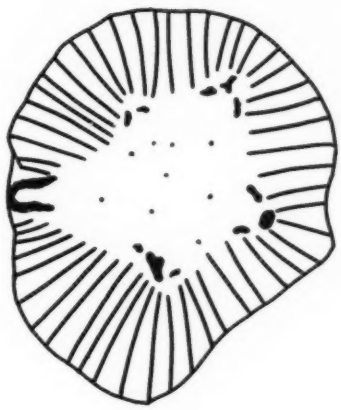

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FIGS. *1, 2—Lycopogenia callicyrta* Read, n. gen. and sp., *1*, diagram of the lobate xylem, ×8; *2*, camera lucida drawing of a portion of the xylem showing leaf traces and the position of the protoxylem, ×32. *px*, protoxylem. (p. 227)

3, 4—Arnoldella minuta Read, n. gen. and sp.; *3*, diagram of transverse section, ×6; *4*, camera lucida drawing of the stele and adjacent tissues, ×15. *px*, protoxylem; *t*, trace; *gc*, gum canal. (p. 221)

5—Kalymma auriculata Read, n. sp., diagram of transverse section, ×6. (p. 220)

6—Calamopitys foerstei Read, n. sp., diagram of transverse section showing the relationships of the bundles of the primary xylem, ×2½. (p. 219)

quence in this type of stem structure. In the English *S. tuedianum* Kidston there is a slight development of secondary xylem on the abaxial side of the trace. No secondary growth was noted in the case of the American material.

Diichnia is obviously a calamopityean type closely related to *Eu-Calamopitys*, but it is quite distinct because of its double leaf trace. Also the primary xylem bundles are much reduced and more widely separated than in *Calamopitys*. *Diichnia* may, in fact, be regarded as a type much more advanced than *Calamopitys*.

Stenomyelon Kidston is usually placed in a separate family, the Stenomyeleae. The placing of this genus in the Calamopityeae and the discontinuance of the segregate Stenomyeleae therefore need a word of explanation. It appears to the writer that *Stenomyelon* is closely allied to *Calamopitys*, the critical differences being the more pronounced woody nature of the so-called "mixed pith," the slightly differentiated protoxylem, and the reduction of secondary growth in the leaf trace. On the other hand, the morphology of the primary xylem in the stem and, more particularly, in the leaf trace, the polydesmic nature of the petiole, and, in fact, the whole aspect of the axis are those of a modified eu-calamopityean type. The xylem of the leaf trace in the American *Stenomyelon* here described is strikingly like the primary xylem in the trace of *Calamopitys americana* Scott and Jeffrey. The slight differentiation of the protoxylem except in the vicinity of an emerging leaf trace might be taken as a marked difference with known Calamopityeae. However, in *Calamopitys americana* Scott and Jeffrey the protoxylems are likewise inclined, in some specimens, to be vague.

Calamopitys americana Scott and Jeffrey

Plate 27, figure 1

The general features of *Calamopitys americana* Scott and Jeffrey are shown in Pl. 27, fig. 1. The material in the writer's collection is much more complete than that described by the authors of the species and is particularly illuminating in connection with the morphology of the leaf trace. The following statements summarize the knowledge of this form:

1. Pith mixed, the medullary tracheids variable in bulk.

2. Primary bundles mesarch, the protoxylem tending to be exarch; the bundles numerous and forming a discontinuous ring.

3. Secondary xylem with multiseriate rays, the pits of the tracheids in several rows, oval or hexagonal.

4. Cambium, phloem, and pericycle apparently forming a marked zone outside the wood.

5. Cortex chiefly large-celled parenchyma.

6. Hypodermis of the sparganum type.

7. Leaf traces originating from a single protoxylem group which divides tangentially to form a leaf-trace strand and a reparatory strand which remains at the margin of the pith. The leaf-trace bundle divides along a radial plane almost immediately to form two partly fused mesarch bundles which diverge as they pass through the secondary wood. These bundles carry considerable secondary xylem through the outer tissues of the stele but quickly lose this in the inner cortex. Repeated division of the bundles gives rise to a

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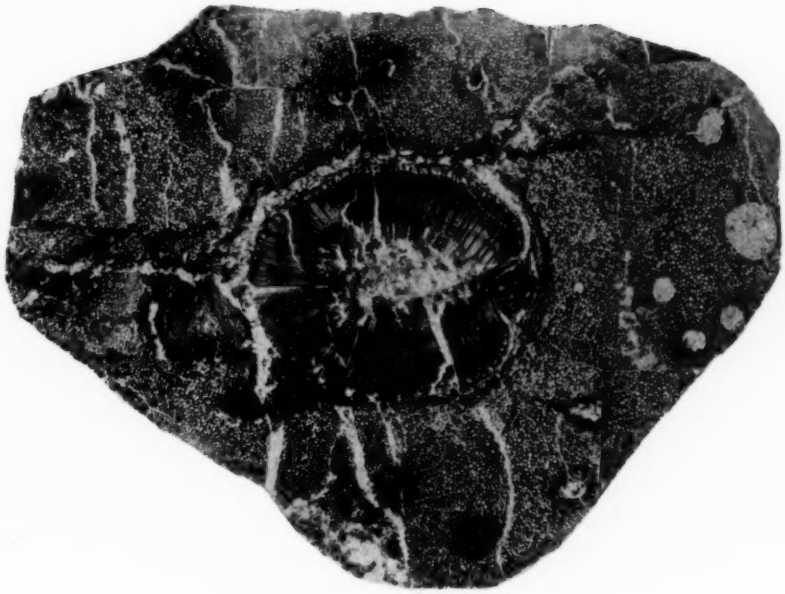
Explanation of Plate 27

Figs. *1*—*Calamopitys americana* Scott and Jeffrey, transverse section, ×3, of a well-preserved stem showing general appearance; note emerging leaf trace and numerous petiole bases. This illustration is a mosaic prepared from a series of photomicrographs. (p. 218)

2—*Diichnia kentuckiensis* Read, n. gen. and sp., transverse section of stem, ×3. Mosaic of photomicrographs. (p. 219)



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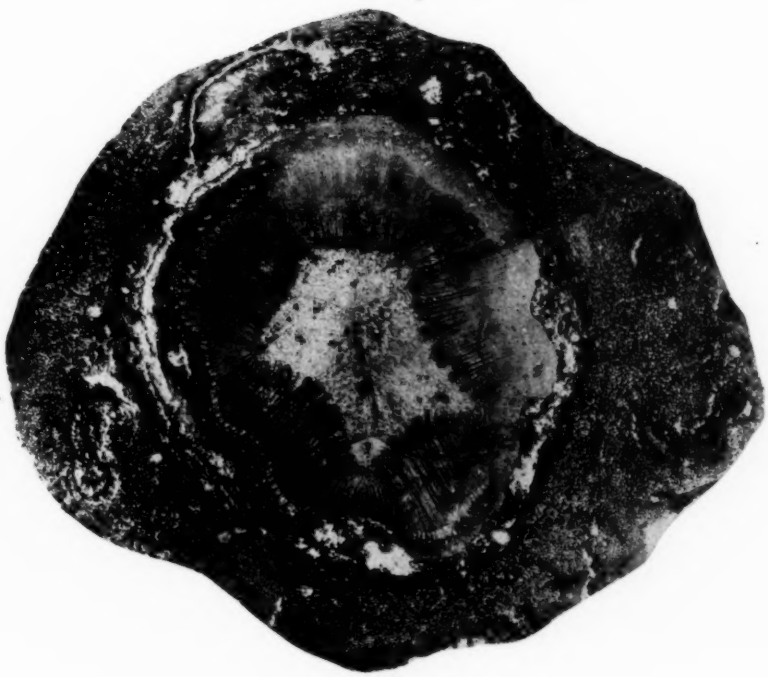

2

Read, Devonian Plants

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polydesmic petiole to be described as *Kalymma*.

8. Phyllotaxy approximating three-eighths.

CALAMOPITYS FOERSTEI Read, n. sp.
Text-figure 6

The plant here described from its stem appears to be a type intermediate between *Diichnia* and *Calamopitys americana*. In the nodal morphology it falls within the range of the genus *Calamopitys* and in consequence has been assigned to that group, although it must be admitted that the generic distinction in this case is difficult. Only the woody cylinder and pith are preserved, and the diagnosis given below is incomplete.

1. Woody cylinder in the type specimen large, the wood typical eu-calamopityean with multiseriate rays.

2. Pith large, five-angled, only slightly "mixed," parenchymatous.

3. Primary bundles few in number, restricted to the angles of the pith, embedded in the parenchymatous pith except in the case of bundles immediately connected with emerging traces, mesarch.

4. Leaf trace derived from two adjacent primary bundles situated at an angle of the pith. The outward passing bundles unite insofar as the metaxylem is concerned, although the protoxylems remain distinct. The main bodies of the primary strands remain in the pith as reparatory bundles.

5. Phyllotaxy probably two-fifths.

6. Gum canals absent in the pith.

DIICHNIA KENTUCKIENSIS Read, n. sp.
Plate 27, figure 2

A form very closely related to *Calamopitys* of the *C. americana* type (*Eu-Calamopitys*) departs in certain respects from the generic characters set up for *Calamopitys* and has, in consequence, been placed in a new genus. Briefly, its critical features are:

1. The broad, five-angled pith with occasional strands of xylem and lysigenous canals.

2. The widely spaced mesarch bundles of primary xylem at the margin of the pith.

3. The broad-rayed secondary xylem abutting directly on the pith except in the vicinity of the angles.

4. The diarch leaf traces, the two bundles originating from adjacent angles of the pith.

5. The tangential elongation of the bundles of the polydesmic leaf base after they have begun to divide in the cortex.

6. The two-fifths divergence of the leaves.

KALYMMA LIRATA Read, n. sp.
Plate 28, figure 4

The *Kalymma*-like petioles from the Linietta clay can, for the most part, be included in this species. This material in the past has been placed in *Kalymma grandis* Unger. It is noteworthy, however, that these petioles show very characteristic invaginations both adaxially and abaxially in the ring of vascular bundles, a feature not shown in the figures of the typical *K. grandis* Unger from the *Cypridina* shales at Saalfeld, Thuringia. The morphological features which characterize this form are:

1. Vascular bundles numerous, in a single ring which shows a marked invagination both above and below.

2. Individual bundles tending to be radially elongated as seen in transverse section.

3. Bundles mesarch and apparently concentric, with one or several protoxylems.

4. The mass of the petiole large-celled parenchyma.

5. Hypodermis of the sparganum type.

KALYMMA RESINOSA Read, n. sp.

This species is quite similar to *Kalymma lirata* except for the presence of lysigenous secretory canals in the ground parenchyma. This, however, provides adequate ground for specific distinction. It is suggested that the petioles here designated as *K. resinosa* may be correlated with *Diichnia kentuckiensis*, the occurrence of the gum canals being rather strongly suggestive of this.

KALYMMA GRANDIS Unger

Scott and Jeffrey mention in their report on the Linietta flora the occurrence

of *Kalymma grandis* Unger near Junction City, and figure a number of specimens. Their present writer is of the opinion that the material figured should be referred to *K. lirata* Read, but since he has seen only the recent collections and has not had the opportunity to examine the material described by Scott and Jeffrey, he cannot be certain. It seems best, therefore, to list this Thuringian species from Junction City.

KALYMMA AURICULATA Read, n. sp.
Text-figure 5

This species may be characterized as follows:

1. Petioles small to medium in size.
2. Vascular bundles several, in a single ring.
3. Bundles usually two large adaxial(?) and several small abaxial(?), the structure eccentrically mesarch (tending towards exarchy) and concentric.
4. The two large adaxial(?) bundles with several protoxylems and characterized by prominent bulges in the xylem, as shown in the diagram.
5. Groundmass large-celled parenchyma.
6. Hypodermis of the sparganum type.

CALAMOPTERIS HIPPOCREPIS Scott and Jeffrey

The material described by Scott and Jeffrey as *Calamopteris hippocrepis* is, as those writers stated, very closely related to *Kalymma*. Particular emphasis was placed at that time on the invaginations of the ring of bundles. In view of the similar invaginations in material which is here described as *Kalymma lirata* there is perhaps little reason for placing these two forms in separate genera. The lateral fusion of the vascular bundles which marks *C. hippocrepis* may be interpreted as no more than an extreme variation of *K. lirata*, in which lateral fusion is common although not to so marked a degree as in the form here discussed. For the present, however, it seems desirable to maintain this genus and species as distinct. In other than the features described above the petioles seem to be identical.

STENOMYELON MURATUM Read, n. sp.
Plate 29, figure 1

The collection obtained by the writer contains a single stem and several petiolar fragments of a plant which finds its closest relationship with the forms described under *Stenomyelon*, from the Calciferous sandstone of England. Briefly it is characterized by:

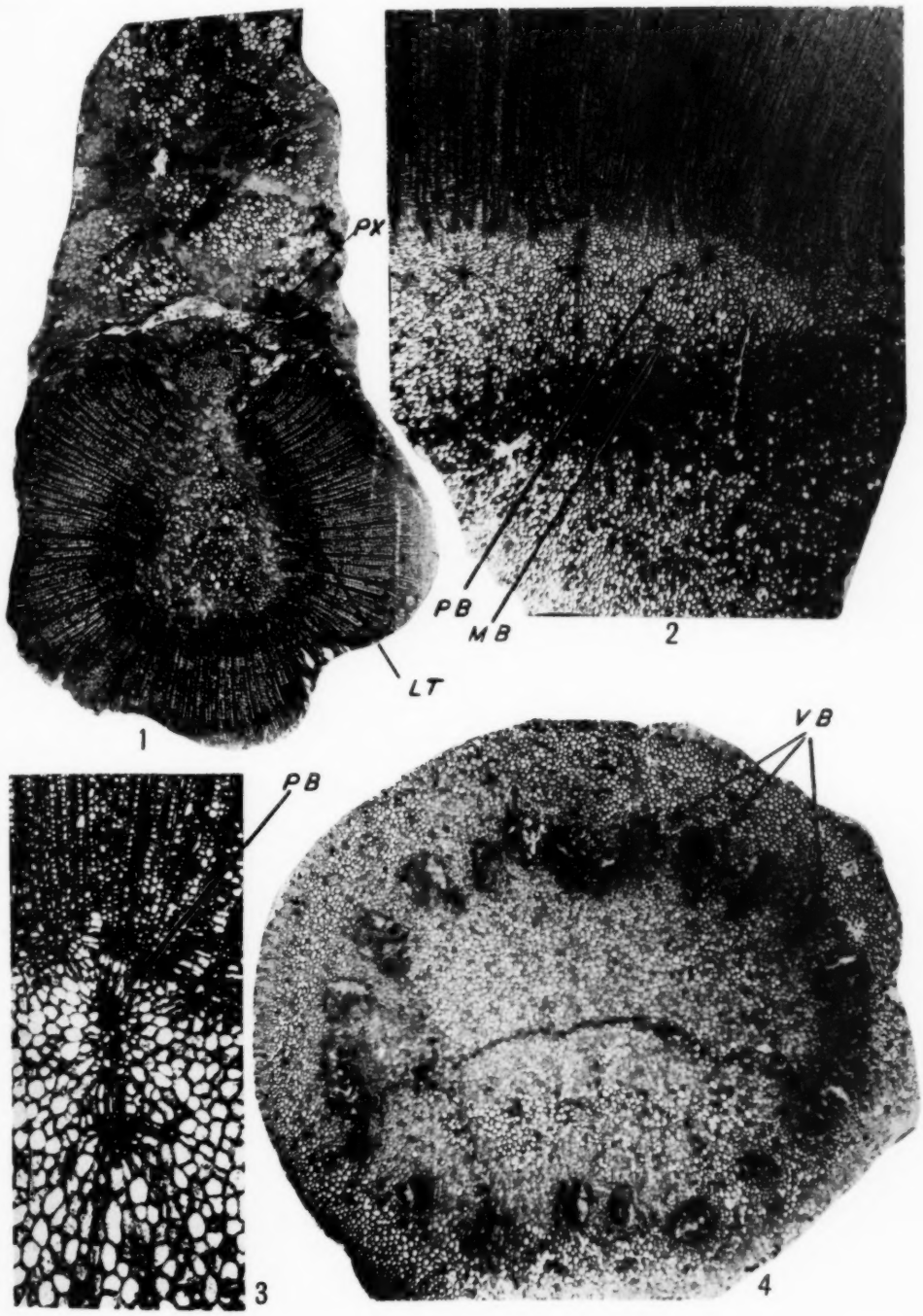
1. A mixed three-angled pith in which the primary xylem is undifferentiated into protoxylem except in the advent of an emerging strand to supply the leaf.
2. A rather broad zone of secondary growth characterized by numerous multiseriate rays.
3. A narrow zone of poorly preserved phloem and pericycle.
4. A broad zone of cortex.
5. Leaf traces passing outward from the angles of the pith in a one-third divergence. A protoxylem develops at the angle occupying an eccentrically mesarch position and gaps the stele widely as it emerges. At the same time it divides into two bundles in the course of its passage through the secondary wood and further divides to form a polydesmic leaf base.

EXPLANATION OF PLATE 28

FIGS. *1*—*Stenomyelon muratum* Read, n. sp., transverse section of the stem, ×6. *lt*, leaf trace; *px*, protoxylem of leaf trace. (p. 220)

2, 3—*Archaeopitys eastmannii* Scott and Jeffery, transverse section, ×6, of a portion of the stem showing relations of primary and secondary wood; portion of same section, ×20. *pb*, peripheral or circum-medullary bundle; *mb*, medullary bundle. (p. 221)

4—*Kalymma lirata* Read, n. sp., transverse section, ×6, showing the arrangement of the vascular bundles of the petiole. *vb*, vascular bundles. (p. 219)



Read, Devonian Plants

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PERIASTRON RETICULATUM Unger

Plate 29, figures 1, 3

The material from Kentucky segregated under *Periastron* seems to be referable to two species, *P. reticulatum* Unger and *P. perforatum* Scott and Jeffrey. The features characterizing *P. reticulatum* may be summarized as follows:

1. Petiole, judging from the fragments, oval or elliptical in cross section.
2. Vascular system consisting of several bundles arranged in a median row.
3. Bundles concentric in structure.
4. Tracheids scalariform.
5. Cortex consisting of interwoven strands and branches of parenchyma forming lacunae.
6. Hypodermis sclerotic, gum canals present.

PERIASTRON PERFORATUM Scott and Jeffrey

Except for the absence of gum canals in the sclerotic hypodermis, this species is identical with *Periastron reticulatum* Unger. This feature, however, is of sufficient importance to provide specific differentiation.

PITYEAE

PITYS BROWNII Read, n. sp.

Plate 29, figures 4, 5

This species may be characterized as follows:

1. Pith large, parenchymatous, without medullary or circum-medullary strands.
2. Primary xylem in discrete mesarch bundles at outer edge of pith, sometimes separated by a small amount of parenchyma from the secondary wood, sometimes in direct contact.
3. Rays dilated at inner margin of wood, narrowing quickly to uni- or bi- or tri-seriate types.
4. Secondary wood cordaitalean.
5. Leaf-trace anatomy not known.

This form is best referred to the genus *Pitys* in view of the structure of its primary wood, despite the absence of medullary and circum-medullary strands.

ARCHAEOPITYS EASTMANII Scott and Jeffrey

Plate 28, figures 2, 3

Numerous specimens have been collected from the Junction City locality. The species has been fully treated by the original authors, and only a summary account is given here:

1. Pith parenchymatous, carrying numerous mesarch medullary strands of xylem.
2. Additional mesarch bundles present at the inner face of the secondary xylem (the circum-medullary strands of Scott and Jeffrey).
3. Circum-medullary strands passing outward as leaf traces, the traces being concentric.
4. Reparatory bundle left behind and becoming medullary as result of division of emerging leaf trace bundle.
5. Primary bundles characterized by not infrequent division.
6. Secondary wood dense, rays both uni- and multi-seriate; in general, narrow.

ARNOLDELLA Read, n. gen.

ARNOLDELLA MINUTA Read, n. sp.

Text-figures 3, 4

Both genus and species may be characterized as follows:

1. Petiole small, round, with a central archlike strand of xylem.
2. Primary xylem mesarch with several protoxylems.
3. Phloem presumably on convex face of stele, not entirely evident.
4. Groundmass of petiole composed of parenchyma with numerous lysigenous canals present.

The writer has been unable to discover any record in the literature of petiole closely approaching this type. Presumably it is pityean in its affinities, although this is difficult to demonstrate.

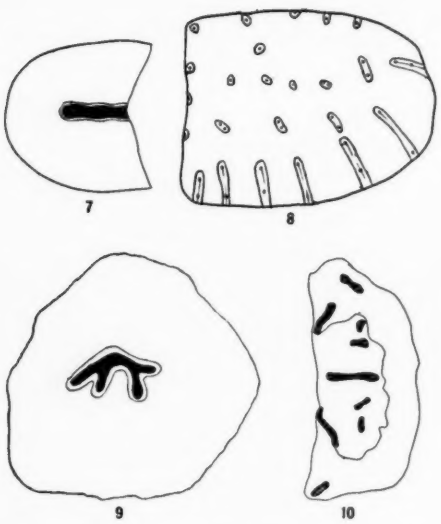


FIG. 7—*Clepsydropis titan* Read, n. sp., diagram of transverse section showing the form of the vascular bundle, ×1½. (p. 222)

8—*Cladoxylon* sp., diagram of a fragment showing the arrangement of the bundles and position of the protoxylem, ×2¼. (p. 223)

9—*Microzygia lacunosa* Read, n. gen. and sp., diagram of a transverse section showing the yoke-like aspect of the vascular bundle, ×1½. (p. 223)

10—*Hierogamma jeffreyi* Read, n. sp., diagram of a transverse section, ×3. (p. 223)

PALAEOPTERIDALES

CLEPSYDROPSIS CAMPBELLI Read, n. sp.

Text-figures 11, 13

This species may be characterized as follows:

1. Phyllophores small, averaging around 5 mm. in diameter.

2. Stele of the typical clepsydropsoid form as illustrated in text-fig. 11 and with rather large loops. Phloem apparently completely surrounding xylem.

3. Cortex of large, rather thick-walled cells poorly preserved.

4. Numerous rootlike organs traversing the cortex at almost right angles to the long axis of the phyllophore and inserted on the stele. These rootlike organs with stele which has a concentric structure. Details not discernible owing to poor preservation.

5 Pitting of xylem in all cases scalariform.

CLEPSYDROPSIS TITAN Read, n. sp.

Text-figure 7

1. Petiole of rather large size, about 12 mm. in diameter.

2. Stele elongate and narrow in transverse section, the two poles only slightly bulging.

3. Peripheral loops or protoxylem areas large, situated as shown in the diagram.

4. Xylem surrounded by a narrow zone of almost entirely disintegrated parenchyma which presumably was the phloem.

5. Groundmass of the petiole consisting of an inner large-celled parenchymatous zone which grades into an outer and relatively narrow sclerotic hypodermal area.

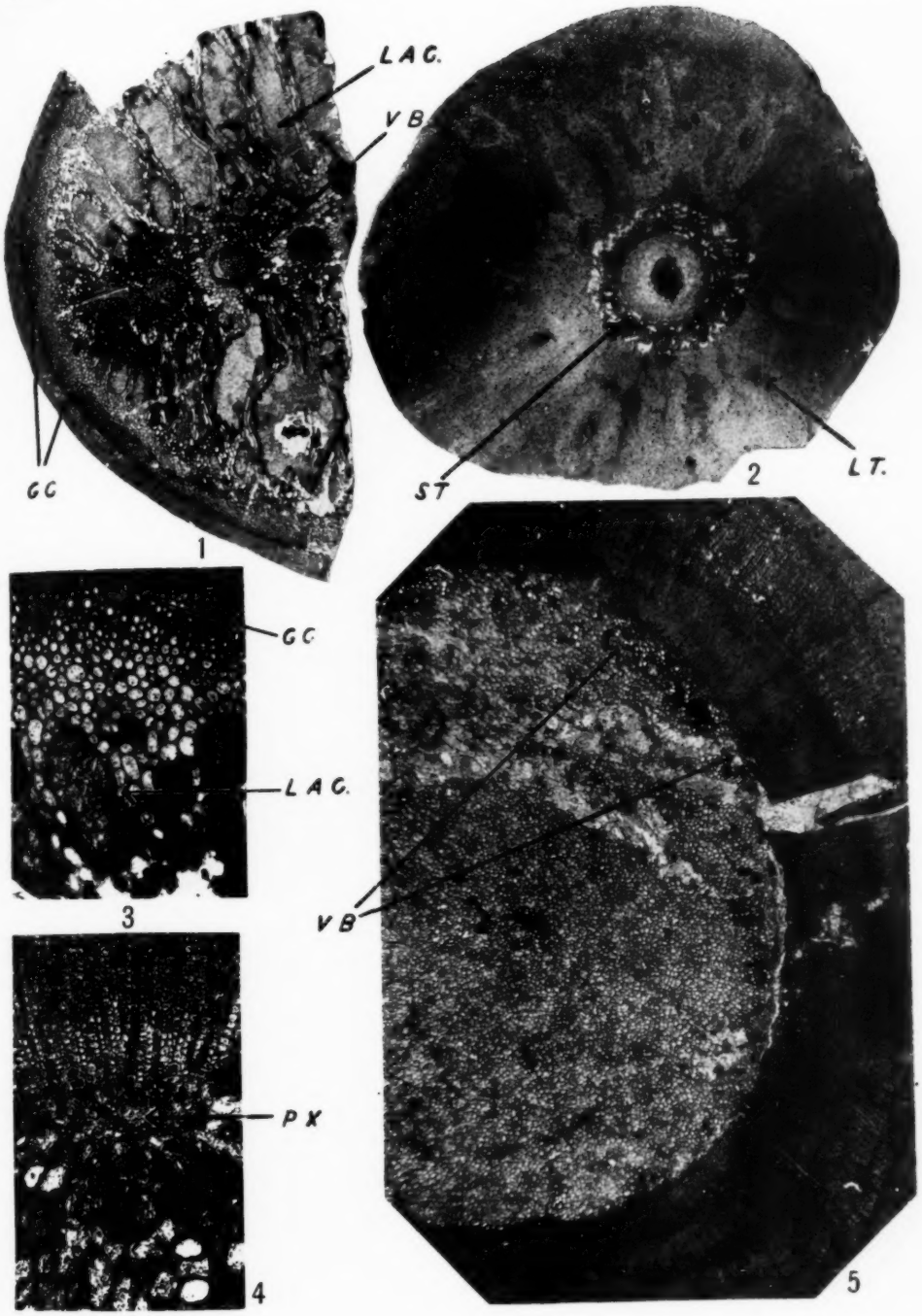
Only a short fragment of this species has been collected. In consequence the form is not particularly well known, although it is felt that the large size and the relatively narrow, elongate cross-sectional outline of the xylem afford ample grounds for specific segregation.

EXPLANATION OF PLATE 29

FIGS. *1*, *3*—*Periastron reticulatum* Unger; *1*, transverse section of a portion of a petiole, ×6; *3*, transverse section of a portion of the cortex and hypodermis, ×20; *lac*, lacunae; *gc*, gum canals; *vb*, line of vascular bundles. (p. 221)

2—*Lepidodendron boylensis* Read, n. sp., transverse section, ×6, of stem showing the small stele (*st*), the broad cortical zone, and the numerous emerging leaf traces (*lt*). (p. 226)

4, *5*—*Pitys brownii* Read, n. sp., transverse section of a portion of the pith and secondary wood showing the location of the primary bundles, ×20; transverse section of the stem, ×6, showing general appearance, large pith and the vascular bundles. *px*, protoxylem; *vb*, vascular bundles. (p. 221)



Read, Devonian Plants

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STEREOPTERIS ANNULARIS Scott and Jeffrey

The fern petiole described by Scott and Jeffrey under the name of *Stereopteris annularis* has not been found in the recent collections. In consequence, the writer cannot add to the knowledge of this form. It is presumably related to *Clepsydropis*, although obviously this relationship is not close enough to suggest generic affinity.

MICROZYGIA Read, n. gen.

Generic characters at present defined by the single species described below, *M. lacunosa* Read.

This genus, although quite distinct, is rather unsatisfactory. Its affinities are particularly vague. Probably it is a fern, the general aspects of the stele being quite suggestive of a zygopterid alliance. Unfortunately the preservation is such that the protoxylem is obscured. It is likely that this plant was a hydrophyte, the strikingly lacunar groundmass of the petiole being rather indicative of this.

MICROZYGIA LACUNOSA Read, n. sp.
Text-figure 9

This species may be characterized as follows:

1. Petiole of large size with central yoke-like stele and outer lacunar groundmass.
2. Xylem in the type specimen imperfectly preserved, the outline in cross section similar to that of a yoke or double "y." Protoxylem not observable, owing no doubt to the preservation.
3. Phloem presumably occupying an area in which the tissue is destroyed around the xylem.
4. Inner cortex consisting of large-celled parenchyma grading outward into a broad lacunar zone.
5. Lacunar zone consisting of a network of small-celled parenchyma enclosing polygonal intercellular areas.

HIEROGAMMA JEFFREYI Read, n. sp.
Text-figure 10

This species may be characterized as follows:

1. Petiole-like structures of medium size, containing numerous vascular bundles as seen in cross section.
2. Symmetry bilateral on the basis of bundle arrangement.
3. Vascular bundles about 7, arranged as seen in the diagram, figure 10.
4. Xylem similar to that in *Cladoxylon*, the protoxylem groups mesarch and identical in their aspect with the loops of *Cladoxylon*.
5. Tissues immediately exterior to the xylem broken down in the type specimen and no traces of phloem present. Apparently a lacunar zone encloses the bundle mass, its general outline being indicated in the diagram, figure 10.
6. Outer tissues of the petiole-like structure parenchymatous and on the extreme exterior somewhat sclerotic.
7. Bundles of elongate type present in this outer tissue, apparently passing outward to supply lateral appendages.

The single specimen on which this description is based is but a small fragment, and because only a few sections have been obtained, information regarding it is incomplete. In its general aspect this structure seems to conform with *Hierogamma* Unger, to which it is tentatively referred. It is certain that its affinities are with the Cladoxyleae.

CLADOXYLON sp.
Text-figure 8

Several small specimens from the Junction City locality are certainly referable to the *Cladoxylon* Unger. Unfortunately none of these are sufficiently complete to furnish information of value relating to the outer tissues of the stem. However, in material of the same species from other localities in both Kentucky and Indiana, excellent preservation will permit a careful morphological analysis. Since this paper concerns only the flora of the Junction City locality, the latter specimens arenot here discussed but will be described in another paper. There follows a short diagnosis of the fragments:

1. Material consisting of fragments of large stems, although none of the outer tissues are preserved.

2. Bundles as seen in cross section numerous, radiating from a large parenchymatous and sclerenchymatous central area which often contains numerous small bundles. The whole bundle system obviously the product of marked anatomosis and ramification.

3. Xylem entirely primary, arranged in radial anatomosing strands. Protoxylems several, mesarch, situated as shown in the diagram, figure 8.

4. Pithlike central area consisting of both parenchymatous and sclerenchymatous tissue. Occasional xylem bundles embedded.

5. Phloem presumably following the contour of the xylem and occupying a narrow zone not preserved in the fossil material.

6. Groundmass between the bundles chiefly parenchymatous.

SIDERELLALES Read, n. order

SIDERELLA Read, n. gen.

Genotype: *Siderella scotti* Read.

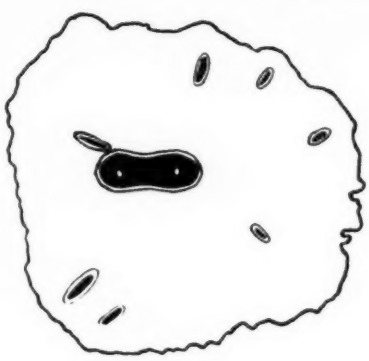
The generic name *Siderella* is here used to designate a plant type from the Junction City locality that presents a combination of characters allying it, on the one hand, to the zygopterid ferns and, on the other, to microphyllous types, possibly the Sphenophyllales. This is a rather important link, if the writer's interpretation of the structures is correct. It is, however, a discovery more or less anticipated by Lignier in his theory of the common origin of the Filicales and the Sphenophyllales (6), which was advanced some 30 years ago and which has received support more recently from Bertrand (7).

Siderella is characterized by stems with stellate steles which are internally parenchymatous. The points of the star are 8 to 10 in the type of the genus, 8 being the most characteristic number, and in the instances of 9 to 10 there is evidence that some of the arms are double. Near the apex of each arm is a poorly defined loop, the "boucle" of French writers. This is, of course, a protoxylem area. Likewise, in the base of each "bay" between the arms of the star there is a mesarch protoxylem. These features are shown in the diagram, figure 12. The xylem of the stem was apparently sheathed on the exterior by phloem, although this tissue is very poorly preserved. The cortex is parenchymatous. It will be noted that two of the arms of the stele, which are directly opposite, are somewhat larger than the others. These two arms give off the characteristic zygopterid phyllophores (branches according to Paul Bertrand) indicated in the diagram, and these phyllophores are opposite (i.e., not alternate). From the other arms of the stele there are given off small concentric traces likewise indicated in the diagram. These are whorled and divide into two or more as they pass outward. It is evident that these last named are true leaf traces of the type characteristic of microphylls, and not unlike those characteristic of the zygopterid aphlebiae. Likewise, they are similar to, although not identical with, the trace of *Sphenophyllum*.

The brief sketch of the morphology of the stem of *Siderella* conveys the idea of an axis giving off whorled appendages; phyllophores on opposite sides, and numerous small leaves. This nodal anatomy is very difficult to understand except on the ground that phyllophores are modified stems and not leaves. The stem, then, may be pictured as an axis giving off opposite branches and whorled leaves.

This phyllophore development unquestionably allies the plant with the Phyllophorales. However, the whorled arrangement of the organ is unusual and is known only in the Cladoxyleae and in the zygopterid *Asteroclaena* Stenzel.

The whorls of small traces very definitely suggest some member of the Articulatae closely related to *Sphenophyllum*. In fact, the general make-up of the stem is rather strikingly suggestive of *Pseudobornia ursina* Nathorst (8), which, it will be recalled, is regarded as sphenophyllaceous in its affinities. It produced pinnatifid leaves in whorls, and at the nodes there were often two directly opposite branches. Particularly is this true in the case of an American repre-



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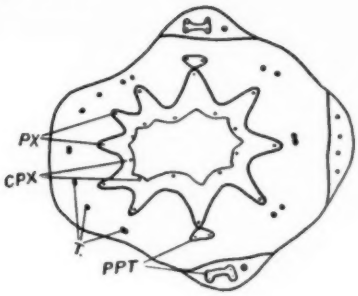

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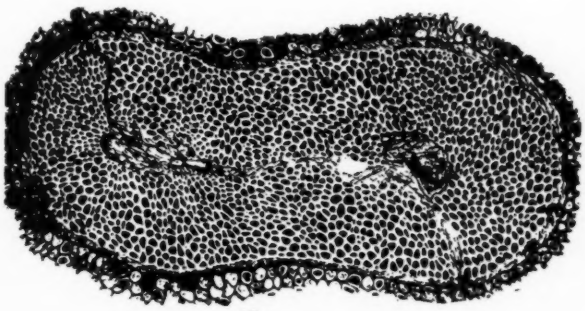

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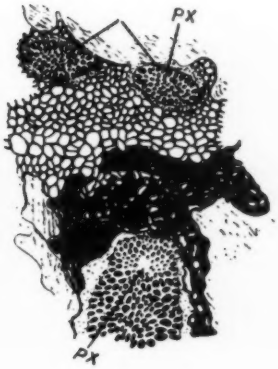

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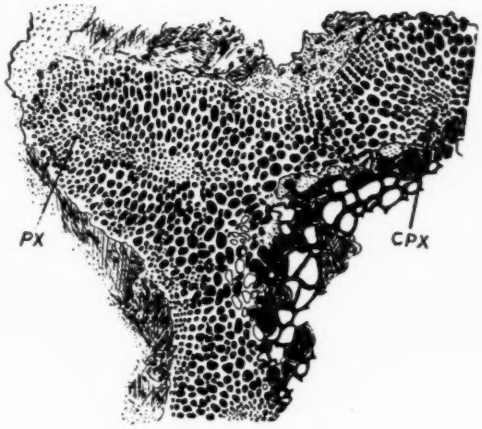

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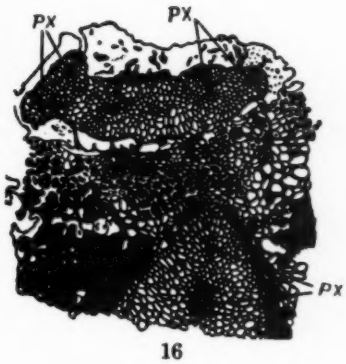

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FIGS. *11, 13—Clepsydropsis campbelli* Read, n. sp., diagram of transverse section, ×7, and camera lucida drawing, ×35. Note adventitious root insertions shown in fig. *11*. (p. 222)

12, 14–16—Siderella scotti Read, n. gen. and sp.; *12*, diagram of transverse section, ×4½; *14*, camera lucida drawing, ×25 showing general appearance of the tip of one of the arms of the stele from which microphyll traces are developed; *15*, details of stelar structure showing protoxylem in the arms and in the bays of the stele, ×25; *16*, one of the arms from which is derived the phyllophore trace shown at the top of the figure, ×25. *px*, protoxylem; *cpx*, protoxylem in the base of the bays of the xylem; *t*, microphyll trace; *ppt*, phyllophore trace, (p. 226)

sentative of the group which will be described. Likewise, some features exhibited by *Siderella* suggest *Cheirostrobus* Scott (9).

A more detailed account of this complex stem will be published in a later contribution. As is stated at the outset, the morphology is suggestive of both the Filicales (Palaeopteridales) and the Sphenophyllales. At present the writer is inclined to regard it as allied more closely with the former but suggests that it be temporarily assigned to a new order, the Siderellales.

SIDERELLA SCOTTI Read, n. sp.

Text-figures 12, 14–16

This species may be characterized as follows:

1. Plants with small stems. Stele large, stellate, arms 8 to 10.

2. Xylem star shaped, primary.

3. Central portion of stele parenchymatous.

4. Protoxylem of two types. (*a*) Small "loops" or "boucles" near the apex of the arms of xylem, mesarch. Protoxylem is apt to be irregularly distributed through the central portion of the arms. (*b*) Areas near the base of the bays of xylem between the arms, mesarch.

5. Radially arranged primary xylem elements common in the bays. These elements are apparently similar to the radial tracheids in *Schizopodium davidi* Harris.

6. Phloem presumably following the exterior contour of the xylem.

7. Appendages whorled, developed from the apices of the arms of the stele, of two types. (*a*) Large H-shaped zygopterid phyllophore traces developed in opposite pairs from two opposite arms of the stele which are more prominent and larger than the others. These traces, when first cut off, are mesarch and triangular. As they gradually develop the characteristic symmetry, the abaxial arms of the antennae become slightly longer than the adaxial. Protoxylems are located at the two poles of the receptrice. (*b*) Small, concentric traces developed in whorls, cut off from the apices of the arms not involved in phyllophore development. These traces divide into 2 to 4 branches as they pass outward. In consequence the trace from each arm shows several bundles in the outer cortex of the stem.

8. Pitting not known.

LEPIDODENDRALES

The lycopodiaceous genera which occur in the Linietta clay are rather interesting because of their bearing on the problem of antiquity of this group of plants. Three genera are now known, two of them based on stem structure and a third on the remains of a single, rather large cone. The cone, *Lepidostrobus Kentuckiensis* Scott, is a type closely related to the well-known *L. brownii* Schimper, from the Lower Carboniferous of Europe. Likewise the stem described here under the name of *Lepidodendron boylensis* Read, is a type falling into the group of *L. harcourtii* Witham. It does, however, differ in several important respects from that well-known type. Finally, there is a stem type which the writer has designated *Lycopogenia callicyrta*, which presents some interesting variations of the somewhat stereotyped lycopsid morphology.

Lycopogenia Read, n. gen.—Stems with a small central stele and a thick cortex; stele concentric, with solid xylem which is somewhat lobate. Protoxylem exarch or slightly immersed. Phloem not preserved in type. Inner cortex thick, parenchymatous, periderm well developed. Leaf traces tangentially flattened in cortex, small; protoxylem in two groups at outer edge of trace. The trace as followed inward gradually fuses with the stele in the manner described for *L. callicyrta* Read, the genotype.

LEPIDODENDRON BOYLENSIS Read, n. sp.

Plate 29, figure 2

This species may be characterized as follows:

1. Stems small, with thick cortex and small centrally situated stele.

2. Stele concentric, the xylem of the general type of *L. harcourtii*. Secondary xylem forming a thin zone.

3. Outer tissues of stele not well preserved.

4. Outer edge of xylem crenulated, with numerous prominent angles.

5. Leaf traces departing from bays between the tracheid ridges; protoxylem mesarch. One bundle apparently passing into each leaf. Phyllotaxy very complex.

6. Cortex consisting of a loosely woven aggregate of parenchyma, simulating in some cases a ramentum.

LYCOPOGENIA CALLICYRTA Reed, n. sp.

Text-figures 1, 2

This species may be characterized as follows:

1. Stems of medium size, with small central stele and thick cortex.

2. Stele solid, circular, with lobate outer margin.

3. Protoxylems situated at the outer edge of the solid xylem mass, exarch or slightly immersed.

4. Secondary xylem not observed.

5. Phloem not preserved.

6. Inner cortex thick, parenchymatous.

7. Periderm developed at outer edge of preserved specimen.

8. Leaf traces tangentially flattened in cortex, small; protoxylems in two groups at outer edge of trace.

9. Trace as followed inward fuses gradually with the xylem of the stele as follows: (*a*) Trace at inner edge of cortex tangentially oval with exarch protoxylem groups. (*b*) As it passes inward it gradually fuses with a lobe of the xylem of the stele. (*c*) As fusion takes place a depressed area develops in the lobe, the trace retaining its identity. (*d*) The depression gradually deepens until the lobe is completely obliterated. (*e*) Finally fusion of adaxial portion of trace and stem xylem takes place, and the outline of the leaf trace becomes obliterated.

This form, represented by several specimens, appears to be definitely related to *Lepidodendron*, but in its markedly lobed protostele and in the unusual aspects of the leaf trace there are found characters which set it apart from that genus as now understood.

LEPIDOSTROBUS KENTUCKIENSIS Scott

The writer has seen no material, in the recent collections, of the cone described by Scott and Jeffrey as *Lepidostrobus fischeri* and afterwards named *L. kentuckiensis* by Scott (10). As has already been indicated, this species closely resembles *L. brownii* Schimper, from the European Lower Carboniferous.

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SOCIETY RECORDS AND ACTIVITIES

PALEONTOLOGICAL SOCIETY: OBITUARIES

The Paleontological Society records with regret the death during 1935 of three Fellows and one Member. These are:

Herdman Fitzgerald Cleland, died January 24, 1935.

Charles David White, died February 7, 1935.

William John Sinclair, died March 25, 1935.

Robert Rossell Rowley, died January 26, 1935.

Memorials of the Fellows will appear in the Proceedings of the Geological Society of America for 1935.

ROBERT ROSSELL ROWLEY

Robert Rossell Rowley, who died on January 26, 1935, was another of that rapidly disappearing group of naturalists whose interests range widely in biological fields. Born January 4, 1854, in Louisiana, Missouri, he showed early the love for nature that grew to be the dominant influence in his life. After graduation in 1875 from the Louisiana High School, he studied geology and paleontology under Prof. G. C. Swallow at the University of Missouri, and other biological and physical sciences. After two years at the University he taught school in Missouri and Arkansas, returning in 1894 as principal to the High School from which he graduated. In 1911 he was made Superintendent of Schools, but continued to teach at least one course in science each year. In various capacities he maintained his connection with the Louisiana Public Schools until his death. The unusually large proportion of the residents of Louisiana, Missouri, interested in natural science is a tribute to his enthusiasm as a student of nature and to his effectiveness in transmitting his enthusiasm to others.

Rowley was a tireless collector. His lifetime collection of fossils is the most complete assemblage extant of Lower Mississippian fossils from the type Mississippi Valley region, and contains in addition many Ordovician, Silurian and Devonian species. In the collection are 221 types, many of species named by Rowley himself. Scarcely of less interest to him than his fossils were his collections of lepidopterous insects. His first collection went to the University of Missouri; his second, and by far the larger, was a source of pleasure to him up to the time of his death. Both collections contain types.

Rowley's scientific publications include 82 papers. His geological publications are mostly on the stratigraphy and paleontology of Missouri, the largest a bulletin of the State Bureau on the geology of Pike County. His contributions to biology deal largely with lepidopterous insects.

Despite the high worth of his published articles, Robert Rowley's greatest contribution was, in the writer's opinion, not in words or ideas on paper, but in the development in his many friends, through his personality, his love of humor, and his love of nature, of broader visions and wider appreciations of the interrelations of all things that have lived and are living now. These are enduring memorials to him that will ever exist in the minds and memories of those who came into contact with him, in youth in his classrooms or in later years as associates in his beloved out-of-doors.

JAMES WILLIAMS

CORRECTION—CATALOGUE OF DEVONIAN FOSSILS

The price stated on page 79 for the unit of 50 cards should have been $2.50, not $2.25.